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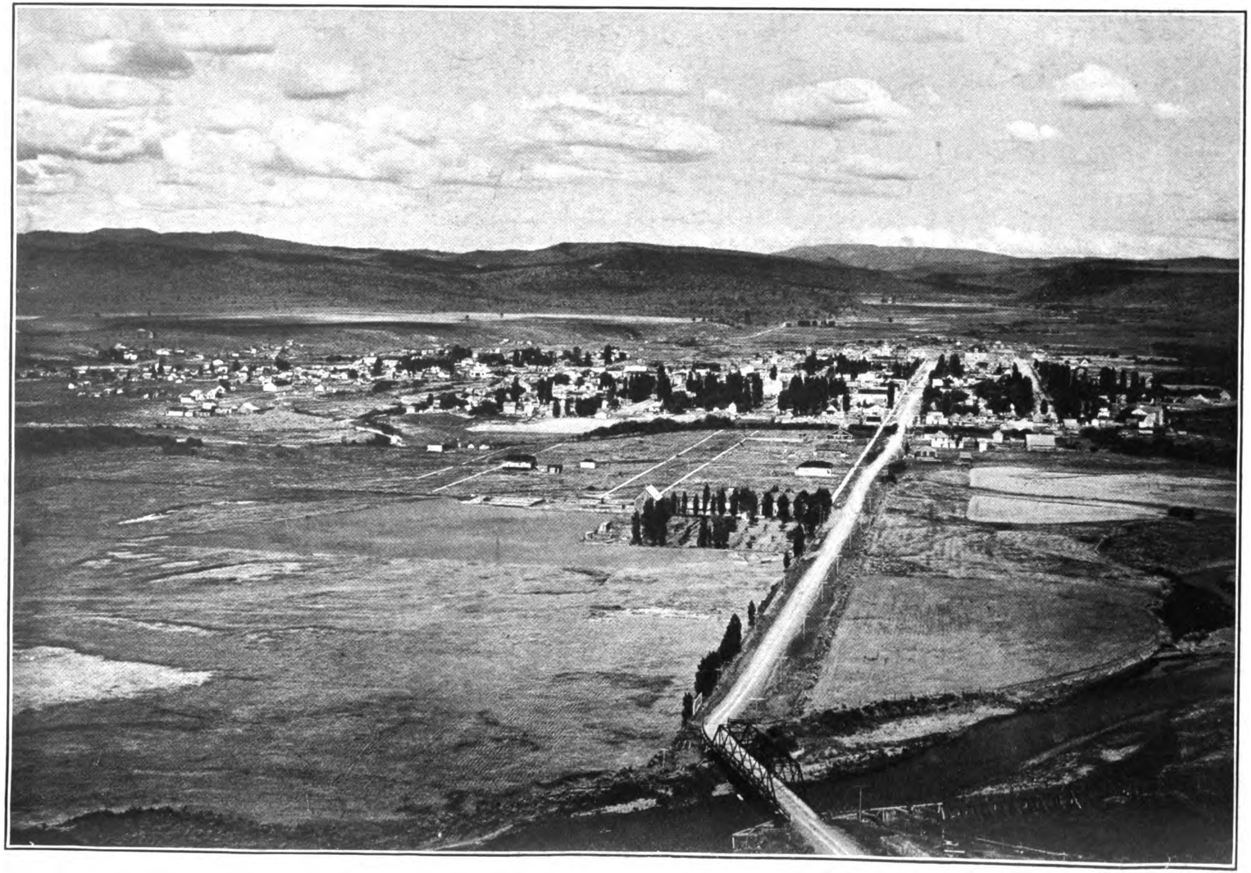

PRINEVILLE FROM TABLE ROCK.

OREGON COOPERATIVE WORK

[2d]

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
IN COOPERATION WITH
STATE OF OREGON

OCHOCO PROJECT
AND
CROOKED RIVER INVESTIGATIONS

BY

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OCHOCO PROJECT AND CROOKED RIVER INVESTIGATIONS.

SYNOPSIS.

This report deals with the irrigation and water-power possibilities of Crooked River basin and its relation to lower Deschutes River power development.

Its principal feature is the Ochoco project for the irrigation of 12,000 to 18,000 acres of land in the vicinity of Prineville.

The work has been carried on by officers of the United States Reclamation Service and the State engineer, under an agreement published in full in the Deschutes project report, which should be read in connection with this report. The Deschutes report was the first of a series of cooperative reports to be issued.

The features to which this report has especial reference are:

(*a*) The Ochoco project, which will provide irrigation for 15,500 acres in the vicinity of Prineville, by storage of 40,000 acre-feet in a proposed reservoir on Ochoco Creek, 6 miles above Prineville, the spillway for which will be 113 feet above low water. The estimated cost of this project is $51.30 per acre.

(*b*) The irrigation of part of the North unit lands of the Deschutes project by storage on Crooked River at the Post Reservoir site. Several alternative plans are considered, comprising a low-line development to irrigate 46,000 acres near Haystack Butte, and 9,000 acres near Prineville, with 50 miles of main canal, and water by storage through the construction of a 131-foot dam above Post at a cost of $78 per acre; a high-line development for Haystack Butte lands, and all of Ochoco project lands at a cost of $83 per acre.

(*c*) A study of the availability of Crooked River storage for increasing the minimum flow of lower Deschutes River for various hydroelectric power developments proposed in United States Geological Survey Water-Supply Paper 344. A fall of 200 to 300 feet in lower Deschutes River must be developed before Crooked River storage at its estimated cost becomes feasible for this purpose.

The purpose of this cooperative work is "to provide for detail surveys and investigations of the water resources of the State of Oregon," with particular reference to irrigation and power possibilities.

Funds for conducting the work are provided in an appropriation of $50,000 by the State of Oregon, and allotment of an equal amount by the Secretary of the Interior from the Reclamation fund. All available data heretofore obtained by the Reclamation Service for projects in Oregon other than those under construction are also made available by special agreement. The estimated present value of such additional data is $25,000.

The irrigable land in the vicinity of Prineville available for irrigation from Ochoco Creek consists of approximately 12,000 acres of bench land and upwards of 5,000 acres of bottom lands.

A duty for water of 1.85 acre-feet per acre of irrigable land is considered reasonable for the Ochoco project on the assumption that at least one-third of the project will be in grains.

The records of discharge for Ochoco Creek furnish fairly complete data for four years. From these data and a comparison with other streams of Central Oregon, for which long records are available, it is estimated that the mean run-off from Ochoco Creek is about 48,000 acre-feet, with an estreme maximum and minimum of approximately 84,000 and 22,000 acre-feet during the past 12 years. This minimum is for the present year, which in all probability will be the lowest for 25 years or more.

All the available run-off from Ochoco Creek during the irrigation season, in ordinary years, is now appropriated. A reservoir on Ochoco Creek with a dam about 6 miles above Prineville is proposed, to provide about 40,000 acre-feet storage. This is about the mean unappropriated run-off of Ochoco Creek. Carry-over storage from high to low years is not provided, owing to the relatively high cost of storage for this project.

The distributary canal system is exceptionally compact, the storage dam serving also for diversion, and the irrigable lands begin immediately below. The larger part of the main canal is designed to be concrete lined and all structures are planned to be of concrete.

Soil and agricultural surveys of irrigable lands show the soils to be from 2 to 4 feet or more in depth, with the physical character for irrigation and cultivation good. The plant food content of the bench lands is fair and for the bottom lands excellent.

Little or no drainage will be required for the bench lands. Alkali and ground water conditions indicate that probably half the bottom lands require drainage at the present time. The cost of drainage will be relatively low because the distance is very short from the limit of the bottom lands at all points to either Ochoco Creek or Crooked River channels.

No estimates have been included in this report for drainage.

The estimated cost of Ochoco storage, including reservoir lands is $564,400, the estimated cost of the distributary canal systems is $231,200, a total of $795,600. Most of the bottom lands and certain of the bench lands have partial or incomplete water rights from

Ochoco and McKay Creeks. Of a total of 17,700 acres of irrigable area, it is estimated that there will be the equivalent of 15,500 acres of land requiring a full water right. The total estimated cost of the storage and distributary system is therefore $51.30 per acre.

Owing to the compactness of the project, it is believed the annual operation and maintenance charges will be comparatively low and should not exceed 75 cents per acre.

Surveys and diamond drill borings show an excellent reservoir site on Crooked River about 10 miles above Post. This is the only feasible storage site on Crooked River.

Records are available of the discharge of Crooked River at Post for three years and at or in the vicinity of Prineville for six years. From these records and information as to other streams in central Oregon, it is estimated that during the period 1907 to 1915, inclusive, the mean annual run-off of Crooked River at Post was approximately 216,000 acre-feet, with a maximum of nearly 350,000 acre-feet and a minimum of 125,000 acre-feet.

The cost of storage at Post reservoir site per acre foot of capacity is relatively low, being cheapest for a storage capacity of about 270,000 acre-feet, with an estimated mean run-off of approximately 215,000 acre-feet available. A reservoir capacity of 260,000 acre-feet has been taken as the basis of investigations for this river, thus providing a carry-over storage capacity of approximately 45,000 acre-feet in excess of the mean run-off.

Storage for a capacity of 260,000 acre-feet will require the water to be raised 131 feet. The estimated cost of a dam to raise the water to this height is $732,000. The estimated cost of lands in the reservoir site is $145,000, a total of $877,000, or a little less than $3.40 per acre-foot of capacity.

By a long canal, diverting about 12 miles above Prineville and extending through the irrigable lands of the Ochoco project to the irrigable lands of the north unit of Deschutes project (see Deschutes project report), a distance of approximately 50 miles, it will be possible to serve about 46,000 acres of the 100,000 acres in the north unit of the Deschutes project and approximately 9,000 acres of the Ochoco project lands.

By diversion about 3 miles farther up Crooked River it would be possible to cover approximately the entire area of the Ochoco project lands, though at a considerably higher cost.

These upper lands of the Ochoco project might also be served from the low-line diversion by electric power pumping.

The estimated cost of serving the 46,000 acres of the north unit of Deschutes project, known as the Haystack Butte country, and 9,000 acres of the Ochoco project lands, a total of 55,000 acres, is a little less than $78 per acre. The estimated cost of water for these lands from Deschutes River was a little less than $56 per acre. (See Deschutes project report, p. 137.)

By the high-line diversion to cover all of the Ochoco project lands the total estimated cost per acre is a little over $83.

Consideration of plan to serve only lands of the Ochoco project from Crooked River storage, with high-diversion and gravity system, shows the cost per acre of land served to be approximately $69. With an alternative low diversion, electric power pumping of a maximum lift of 125 feet, the development of power at Dillon Falls, transmission line for pumping plant, and capitalization and maintenance costs the estimated cost per acre served is little less than $90. It is evident, therefore, that the irrigable areas available for irrigation from Crooked River can be more economically served from other sources.

A study of the value of Crooked River storage for regulation of discharge of lower Deschutes River for power development at the several power sites referred to in United States Geological Survey Water-Supply Paper 344 shows that until a total head of approximately 200 feet is developed on the lower river Crooked River storage will not be economical. This is on the assumption of a developable modified flow of approximately 4,000 second-feet minimum below the mouth of White River.

In a similar manner it is shown that a head of not less than 200 feet must be developed before Crooked River storage, at its estimated cost, will be of economic value for sites above the mouths of Warmspring and Metolius Rivers.

There being no feasible power sites on Crooked River itself of sufficient magnitude to justify storage, it may therefore be said that Crooked River offers no attractions as a power stream either by itself or in connection with Deschutes River.

INTRODUCTION.

AUTHORITY.

Authority for Oregon cooperative work and this report is found in the act of Congress of June 17, 1902 (32 Stat., 388), commonly known as the reclamation act, and subsequent, supplementary, and amendatory acts, on the part of the United States, and an act of the legislature, chapter 87, General Laws of Oregon, for 1913, on the part of the State of Oregon.

The reclamation act and its amendments by Congress are generally well known and are therefore not repeated here. Copies of the original act and amendments may be had on application to the United States Reclamation Service, Washington, D. C.

The State law authorizing this work was quoted in the Deschutes project report and need not be repeated.

AGREEMENTS.

AGREEMENT MAY 5, 1913.

Under authority of these acts of Congress and the State Legislature, an agreement was entered into between the United States and the State of Oregon, under date of May 5, 1913, which provides for the manner of carrying on the investigations.

This agreement was given in full in the Deschutes project report and will not be repeated here. In general it provides:

1. That surveys and investigations for irrigation projects, with incidental power possibilities, be made in central Oregon.
2. That from time to time, as appears necessary, withdrawals of public lands and waters be made by the Secretary of the Interior and the State engineer.
3. That all investigations be made under a plan agreed upon by the Reclamation Service and the State engineer.
4. That field notes and original data acquired or prepared be filed with the Reclamation Service, accessible at all times to the State engineer or his representative.
5. That on completion of the investigations, a report be published with conclusions and recommendations.
6. That the expense of the work be borne, one-half each by the United States and the State of Oregon.
7. That employees paid by the United States and the State shall be subject to rules and regulations established by each, respectively, and that in the selection of employees preference be given to residents of the State.

SUPPLEMENTARY AGREEMENT.

As contemplated under agreement of May 5, 1913, a plan of operations was jointly agreed upon by the Reclamation Service and the State engineer, under date of July 8, 1913, as to Deschutes River and Crooked River investigations and for preliminary examinations of certain other projects.

FEDERAL AND STATE COOPERATION.

During the past nine years the State of Oregon, through the State engineer's office, has cooperated with the United States Geological Survey in making topographic surveys, conducting hydrographic work, and quite recently in making river surveys to determine water power possibilities of some of the most important streams of the State. During the past two years the State bureau of mines has conducted geologic investigations in conjunction with the United States Geological Survey.

The State, through its Agricultural College, has cooperated with the United States Department of Agriculture in conducting farm experiments and in measuring the volume of water used in irri systems. At the present time work is being carried on by th Department, in conjunction with the State of Oregon and th of Portland, to improve the navigability of Willamette and Co Rivers.

A water power survey of Deschutes River by the United Geological Survey, Water Supply Paper 344, in cooperation wi State of Oregon in 1912, doubtless influenced the State legis and the Federal authorities to initiate the present cooperative since this survey disclosed reservoir capacity sufficient to sto entire excess run-off of Deschutes River at Benham Falls, ov above that available and now largely appropriated for use the irrigating season.

Investigations of the possibilities of power development Columbia River at Celilo Rapids were made during the past y

ORGANIZATION FOR THESE INVESTIGATIONS.

Field surveys and office studies, on which this report is have been made by State and Federal engineers under the di of John T. Whistler, engineer, United States Reclamation S and conforming to the general plan specified in the supplem agreement between the Reclamation Service and the State by Hopson, supervising engineer, United States Reclamation S and John H. Lewis, State engineer. The report has been pr by or under the direction of John T. Whistler in conferenc John H. Lewis, and is subscribed to by them on behalf of the erating Federal and State authorities. Attention is, ho directed to the fact that the subscription to this report by offic the Reclamation Service and the State does not commit other off of the Government or of the State to the conclusions reached h

Field work, except the survey of Post reservoir site, was don C. M. Whelan, who has also assisted in the computations and preparation of the Ochoco part of the report. Post reservoir survey was made by W. R. Parkhill.

The studies and computations for the Crooked River investigat part of the report have been made by C. E. A. Bennett, who has assisted in the preparation of that part of the report.

James Dopson was drill foreman in charge of party which put do the test drill holes at Ochoco and Post reservoir dam sites.

Use has been made of preliminary investigations of Crooked Ri and Ochoco projects by Joseph Jacobs for the Reclamation Servi in 1908.

The soil survey was made by W. L. Powers, assistant professor irrigation and drainage, Oregon Agricultural College.

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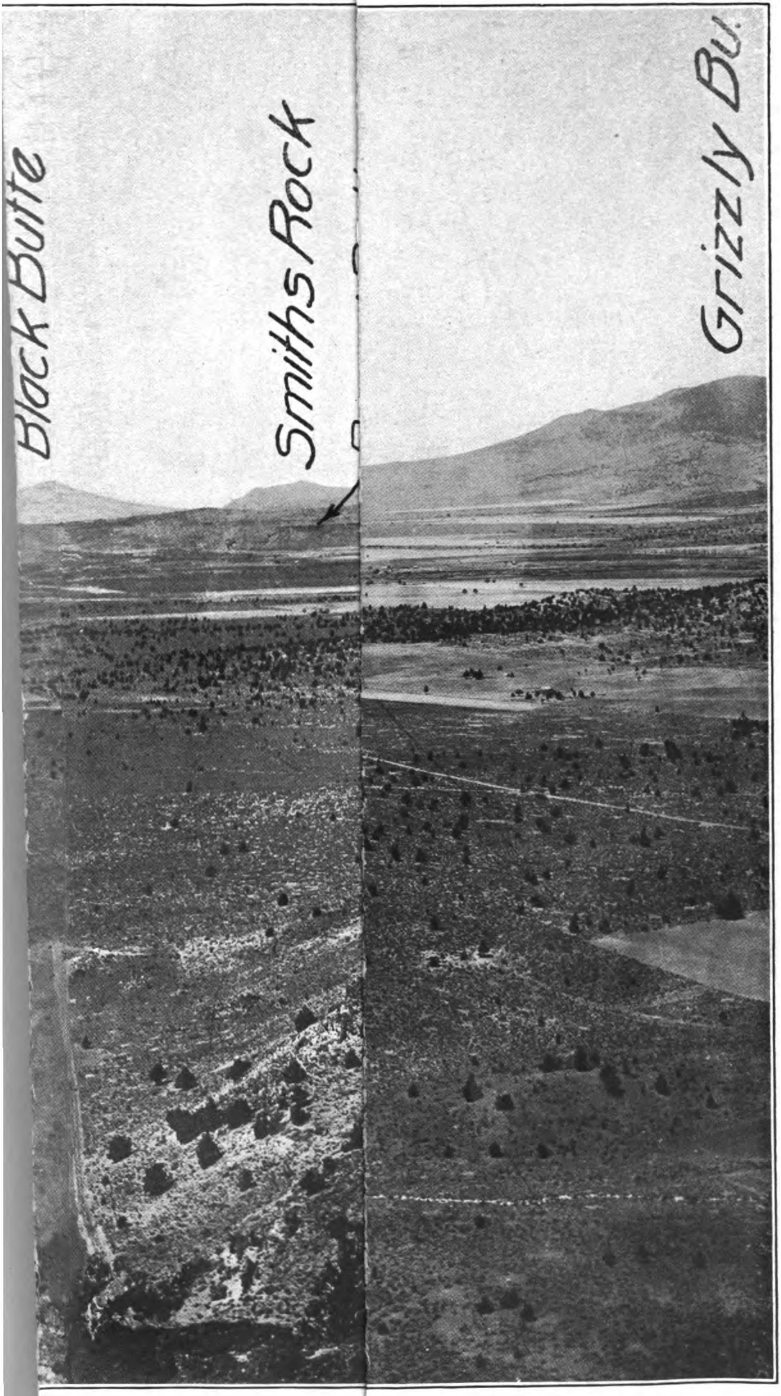


NG WEST FROM BARNES BUTTE.

CROOKED RIVER BASIN.

General description.—The Crooked River drainage basin and its relation to Deschutes River, into which the Crooked River discharges, is shown on Plate No. 34.

Crooked River proper rises in T. 21 S., R. 22 E., and flows north to a few miles west of Paulina, where it is joined by Beaver Creek from the east, one of its most important tributaries. From the mouth of Beaver Creek, it flows in a westerly direction to about 15 miles above Prineville, from which point it has a generally northwesterly direction to its junction with Deschutes River a few miles west of the town of Metolius. Throughout most of its course the river is in a canyon which widens here and there for short distances of a half mile or more, and at these points productive stock ranches are found, many of which have ditches to irrigate their lower lands.

At Prineville the canyon widens out into a basin of some 20,000 acres through which flows Ochoco Creek.

At the junction of the main river with the North Fork there is a similar basin which, in conjunction with the very narrow canyon immediately below the mouth of North Fork, affords an excellent reservoir site. This reservoir site has been discussed for many years and was the subject of a preliminary investigation by the Reclamation Service in 1908.

The drainage basin of Crooked River on the south extends into the Great Basin country and its limits are very indefinite. The best information obtainable, however, indicates that the drainage basin, in years of extreme precipitation, would extend well toward Wagontire Mountain and take the run-off from Hampton and Cougar Buttes.

On Plate No. 34 there is shown what is locally referred to as Dry River Bed, or Old River Bed. In years of high run-off this river bed contains running water over parts of its course. This is without doubt the channel of a stream which at one time must have carried a very considerable amount of water.

Russell, in United States Geological Survey Bulletin No. 252, describes it as "the bed of an ancient stream known as Dry River which at one time drained the great sandy desert."

The course of this old river channel is as well marked as that of Crooked River itself for probably 40 miles above its junction with Crooked River, a few miles above Smiths Rock.

The upper part of its course is not so clearly defined except in places, but is believed to be approximately as shown on Plate No. 34.

The drainage basin on the south side of Crooked River is a region of comparatively low relief and is often referred to as the "Desert." This desert drainage is broken by Bear Creek Buttes west of Bear Creek, and some low-lying hills east of that stream.

On the north Ochoco Creek and North Fork drain a more or less heavily timbered area sometimes referred to as Ochoco Hills. The streams from the south are frequently alkaline, as a result of which the lands of many of the small ranches above North Fork are quite badly alkalied.

Above Paulina, on Beaver Creek, very extensive alkali fields are found.

With the exception of Ochoco Hills and some scattered regions on the south, the Crooked River basin is generally devoid of timber. The altitude of the drainage basin is roughly between 3,000 and 5,000 feet above sea level. The run-off is irregular and varies greatly from year to year and from one part of the year to another. In times of high discharge the river is very muddy and carries considerable silt.

Geology.—Practically the only official report of any kind on the geology of this region is a preliminary report on the "Geology and Water Resources of Central Oregon," by Israel C. Russell, United States Geological Survey, 1905, Bulletin No. 252, from a reconnaissance made in the summer of 1903.

This report contains valuable and interesting information, and, as it is not generally available, extracts relating to the territory under investigation are presented here.

Some discussion of the geology of this region has also been made in the Deschutes project report, Oregon cooperative work.

The following is from Russell's description of Crooked River:

> This stream, of much importance to the country in which it is located, has its source in a number of copious warm springs about 10 miles east of Hampton Butte, and flows north and west through steep-sided canyons all the way to its junction with the Deschutes, a distance of about 115 miles. In its upper portion, just after leaving the alkaline marsh in which it rises, it receives copious contributions from springs, and in its progress rapidly increases in volume, even in late summer, when there is no surface run-off. It is reported to receive contributions from other springs at various localities along its course until it nears Prineville. Below that town it diminishes in volume, and in late summer its bed near Forest, about 12 miles below Prineville, is frequently dry. This marked decrease is now due largely to the use of the water of the stream for irrigation in the expanded portion of its canyon below Prineville, but under strictly natural conditions it is known to have experienced conspicuous seasonal variations. When the volume of the stream diminishes below Prineville it exhibits the characteristics common to many streams that flow from the uplands of arid regions and suffer absorption and evaporation as they pass through the lower portion of their courses where springs are absent. Owing to the absence of saturation at any but great depths, percolation is away from instead of toward the stream channels, and such flow as persists becomes tepid, more or less alkaline, and unwholesome.
>
> Prineville Valley * * * although small, is of importance on account of the aridity of and general absence of irrigable land in the region in which it is located, and is an exceptional feature in the geography of Crooked River, which in all other portions of its course flows through a succession of narrow canyons.
>
> East of Prineville Crooked River flows west through a rugged valley in which outcrops of soft material carrying fossils are reported to occur. About 6 miles before

B

reaching the town it traverses a narrow canyon with vertical walls of basalt about 650 feet high. The basalt is in well-defined layers, with scoriaceous surfaces, of which at least 7 are exposed. The stream has not as yet cut through the pile of basaltic sheets, although a few miles farther up its course the underlying rocks are exposed. This basalt, so far as can be judged from the facts in hand, is to be correlated with the older and more widely extended lava of the Deschutes plain, though present in several sheets instead of a single one. Only one of the sheets, near the top of the section, however, seems to extend west of Prineville.

Less than a mile above Prineville the canyon of Crooked River becomes abruptly wider, and for 6 miles west of that town has a width of 4 or 5 miles, this abrupt increase being due to the presence of soft material beneath the basalt. The canyon is here bounded on the northeast by rocks (probably rhyolitic tuffs) which formed the border of the old Deschutes Valley. Crooked River flowed across the basalt, cutting a canyon near its margin, and on gaining the soft beds beneath the resistant surface layer widened its canyon, locally, into a valley. On the west and south side of the river where it turns from a northerly to a westerly course, near Prineville, the surface sheet of basalt is but 30 or 35 feet thick. The base of the sheet is scoriaceous, and embedded in it are fragments of the soft shaly beds on which it rests. The fine sediments immediately beneath the basalt grade downward into soft, coarse sandstone 20 to 30 feet thick, below which are coarse, well-worn gravels and other sedimentary beds reaching, in the face of the cliff, nearly to the river. The canyon wall with its rim rock of basalt is about 250 feet high by aneroid measure.

An—

Isolated table with a cap of columnar basalt, * * * stands on the north side of Crooked River about 6 miles west of Prineville, near where the valley changes to a canyon. This remnant, spared by erosion, is by aneroid measure about 250 feet high and is instructive not only on account of its striking topographic form, but because at the base of the basalt there is evidence that the lava of which it is composed while yet molten entered water or at least flowed over a wet surface. The base of the sheet for a thickness of from 3 to 7 feet is open textured, or "shredded" and rough, and has masses of the underlying shale involved in it for a distance of from a few inches to fully 3 feet above the general plane of contact.

At this point—

The valley excavated by Crooked River contracts in width and becomes a canyon, but for a distance of about 6 miles farther, to the vicinity of the former post office known as Forest, * * * there is alluvial land on the borders of the river. * * * The portion of the canyon above Forest is in reality a continuation of Prineville Valley. * * * Below Forest all the way to the Deschutes, a distance of over 30 miles, Crooked River flows through a narrow canyon with essentially and often actually vertical walls, and there is no alluvial land in its bottom. Throughout this portion of the river there is but one place where a team and wagon or even a pack train can be taken across it, namely, at Trail Crossing, about 18 miles below Prineville and 7 miles below Forest.

From near Forest to Trail Crossing, Crooked River has excavated its canyon along the border of the vast lava fields extending from the brink of its left wall westward, and on the right has eroded the base of a rugged mountain composed of light-colored acid tuffs, cut by a great basic dike. The tuffs, under the destructive action of wind and rain, have been sculptured into many remarkable monumental forms. * * * On account of these unique monuments of atmospheric erosion the portion of the canyon to which they add picturesqueness may well be termed "Monument Canyon."

The left, or southern wall of Monument Canyon, approximately 250 feet high, is surmounted by a rim rock of basalt about 40 feet thick, beneath which are soft, unconsolidated, stratified deposits, consisting mostly of tuff.

The north wall of Monument Canyon rises precipitously several hundred higher than the nearly level-crested cliff bordering it on the south, and pres striking contrasts to it in nearly every feature. The mountainlike elevation on north is composed mainly of light-colored, mostly yellowish, tuffs in well-defi beds, which in general dip northeast at angles of 40° to 50°. The beds are of uneq hardness, some being resistant to the destructive action of wind and rain and stan out beyond their neighbors as sharp serrated ridges, along which are numerous pinna and spines. Cutting the consolidated and steeply inclined tuff beds is an imm dike or dark basic rock, probably basalt, which has a width of about 1,000 feet trends northeast and southwest. To the northeast the dike can be traced for a or more, and in its present weathered condition forms rounded hills and domes, spicuous on account of their rich brown colors.

Climate.—In the Deschutes project report, pages 26 to 31 inclusi climatological data for the year 1913, together with means for peri of record, were given for the various localities in Upper Deschu and Crooked River basins from Agency Plains to Crescent, includi Prineville. These will not be repeated in this report but since records for Prineville, 1913, were very incomplete, there will given under "Irrigating Season," Ochoco project, similar data Prineville for the year 1906, which appears to be an average year the period of 18 years of observation.

Water resources.—The head waters of Crooked River are in Blue Mountains of eastern Oregon. The summer run-off is mos from springs in the upper portions of the basin. The discharge Crooked River at Prineville varies from practically nothing in summer to 5,000 second-feet or more during the spring floods. The spring floods are very flashy in the entire Crooked River basin a carry much sediment.

The summer flow of both Crooked River and Ochoco Creek practically all appropriated for the irrigation of bottom lands in t vicinity of Prineville, and between Prineville and the North Fork Crooked River. Detailed records of discharge for Ochoco Creek a Crooked River are given under Ochoco project and Crooked Riv investigations.

Van Winkle in his report on the "Quality of Surface Waters of Or gon," United States Geological Survey, Water Supply Paper 36 says that the waters of Crooked River are somewhat high in conte of dissolved matter. They are rather hard for boiler or laundry us but well suited for irrigation and could be used indefinitely witho causing injurious accumulation of alkali from the dissolved matte in them. No tests of Ochoco Creek waters were made, but there i little doubt that the waters are of a much better quality than Crooke River waters, since there are no surface evidences of alkaline soils in the Ochoco Creek drainage basin.

Irrigable lands.—The body of land in Prineville Valley, comprising approximately 20,000 acres, and a number of relatively small areas

RON

of bottom lands above Prineville are practically the only attractive irrigable areas in the entire Crooked River basin. These, together with the lands of the North unit of Deschutes project which it has been thought feasible to irrigate from Crooked River, are the irrigable areas which are considered in the Ochoco project and Crooked River investigations.

Transportation and markets.—Until quite recently the entire Deschutes basin, including that of Crooked River, has been without rail or water transportation nearer than Shaniko, the terminus of the Shaniko branch of the Union Pacific system.

There are now branches of both the Hill and Harriman systems extending up Deschutes River canyon or near it, as far south as Bend, the nearest points on which, to Prineville, the principal trading center of the Crooked River basin, are Redmond and Terrebonne, distant approximately 22 miles. A railroad has been proposed from Metolius to Prineville but no construction work has been done.

The lumber, mining, and fishing interests of Oregon and Washington, together with the Alaskan trade as already developed will, no doubt, continue to offer a market for all the produce, other than grains, that can be grown in this region for a number of years. There seems to be no doubt that the Panama Canal will materially extend this market not only by offering cheaper transportation to the east for produce grown, but as the lumber, mining, and fishing industries of the northwest are, through its influence, built up, the demand from these and dependent sources for farm produce will in turn increase.

Irrigation projects constructed or proposed.—There are no single large irrigation projects either in operation or proposed. However, water rights more or less complete have been adjudicated for approximately 16,000 acres of land in Crooked River basin above Prineville, and for some 4,000 acres below Prineville, including the people's ditch, diverting near Prineville and covering over 2,000 acres.

A project from either Crooked River or Ochoco Creek, to cover the bench lands north and west of Prineville, approximately 15,000 acres, has been proposed for a good many years.

Because of the difficulty of diverting and carrying water out of Crooked River canyon for this purpose and because of the apparently high cost of adequate storage on Ochoco Creek, plans for irrigating these lands were not seriously considered by anyone prior to 1908, when the preliminary examination already referred to was made by the Reclamation Service.

Dams on lower Crooked River for diverting water are maintained at considerable expense, which, however, the fertility of bottom lands appears to justify.

Power possibilities.—Neither Crooked River itself nor any of its branches can be regarded in any sense as an attractive water-power stream, principally because of the great variation in discharge during the year, but also for the reason that the fall of the river above Prineville is very small.

A few miles below Prineville the river enters a narrow canyon which has considerable fall. The slope in this canyon is approximately uniform to its mouth. Except possibly for very small power projects to utilize the return seepage from irrigation on the upper tributaries, water-power development in this portion of the stream, either with or without the construction of an equalization reservoir, will be impracticable.

The possibilities of Crooked River storage in connection with stream regulation on lower Deschutes River are considered under Crooked River investigations.

INVESTIGATIONS FOR THIS REPORT.

Extent of investigations.—Preliminary surveys in connection with the Crooked River and Ochoco investigations had been made by the Reclamation Service in 1908.

The only purpose of these earlier surveys was to afford a general prospect of the extent of irrigation possibilities, and they were not in such detail as to permit of close estimates.

The results of these earlier surveys, however, have been of much value in outlining, in a preliminary way, the course and extent of the present investigations.

In general, the only lands of any extent in Crooked River basin which it appears practicable to irrigate by any new diversion are the lands in the vicinity of Prineville, approximately 15,000 acres of bench lands and possibly 5,000 acres of bottom lands, the latter having more or less incomplete water rights.

Consideration at various times in the past has also been given to the possibility of irrigating lands in what is sometimes referred to as the Haystack Butte country, between Crooked River and Willow Creek, by diversion from Crooked River somewhere above Prineville. This is a part of the north unit of the Deschutes project and was referred to briefly in the Deschutes project report, page 43.

There had also been proposed, as early as 1903, the storage of Ochoco Creek water by a dam about 6 miles above Prineville, and the irrigation of Prineville Valley lands already described.

The extent of investigations for this report has been practically limited to these possibilities.

Projects developed.—The surveys for possible diversion from Crooked River, and canal to serve Haystack Butte lands, indicated quite early in the course of these investigations that such a scheme would prove at best very expensive and result in a high construction cost per acre of land served.

The topography of a reservoir site on Crooked River about 12 miles above Post, and diamond drill borings at the dam site, show the reservoir site itself to be so attractive that the application of storage at this site to power development on lower Deschutes River has been considered with regard to its future regulating value for periods of low discharge.

Alternative plans for irrigation from Crooked River have been considered, in some of which part, and in others all, of the Prineville Valley lands are included.

Preliminary figures will be given for estimated costs of these various alternatives and the plans discussed, but in a general way it may be said that any of the irrigable lands considered by diversion from Crooked River can be more economically served from other sources. It thus appears that the best use to which the waters of Crooked River can be put will probably be in regulating the discharge of lower Deschutes River for power development whenever some or all of the power projects which have been proposed on lower Deschutes River have been constructed. It is probable that it will be many years before such power development on the lower Deschutes takes place.

The proposal to store Ochoco Creek water to serve both bottom and bench lands of Prineville Valley has been quite clearly defined from the beginning of the investigations, and is largely a question of how much water is available and what the cost of construction will be.

That portion of the report which follows will, therefore, be considered as two separate features, namely, Ochoco project and Crooked River investigations.

OCHOCO PROJECT.

GENERAL DESCRIPTION OF PROJECT.

The Ochoco project contemplates storage of Ochoco Creek water by a dam across Ochoco Creek about 6 miles above Prineville and the irrigation of approximately 17,700 acres of lands adjacent to Ochoco Creek and north and east of Crooked River. These lands extend from a short distance below the proposed dam to the west end of Prineville Valley, from 6 to 8 miles northwest of Prineville, and include some 5,400 acres of Ochoco Creek and Crooked River bottom lands which have a more or less insufficient water right.

The dam site is near the west boundary of Sec. 5, T. 15 S., R. 17 E. The dam will be an earth-fill structure with spillway crest 113 feet above present low-water level. Water will be diverted 33 feet above this low level, and between that elevation and the spillway crest the reservoir capacity available for the project is 40,000 acre-feet. The area covered by the reservoir will be approximately 1,000 acres.

The fertility of the bottom lands has long been recognized. The bench lands, comprising most of the project though relatively un-

productive without water, are nevertheless apparently fertile, and because of their close proximity to the reservoir their preparation for irrigation will cost much less than that of the average irrigation project. The lands are from 50 to 150 feet higher than Prineville. The location and character of the lands is such as to indicate that fruit culture may prove profitable, but in the absence of actual frost and temperature records for these bench lands, and with the lack of transportation facilities, their value for this report will be based on the production of forage and grain crops to supplement the surrounding stock range. See plate No. 34 for location of project.

FIELD WORK.

TOPOGRAPHIC SURVEYS.

The surveys for this project were made during the months of September and October, 1914, and include topography of irrigable lands in Prineville Valley, topography of Ochoco reservoir and dam site, and test borings at the dam site.

The irrigable land topography was developed on a scale of one-half mile to the inch. The method used was to run out a canal line at the highest practicable elevation and fill in the topography below as cheaply as possible in order to determine approximately the irrigable area which the canal could be made to serve and the necessary types and costs of the distributaries.

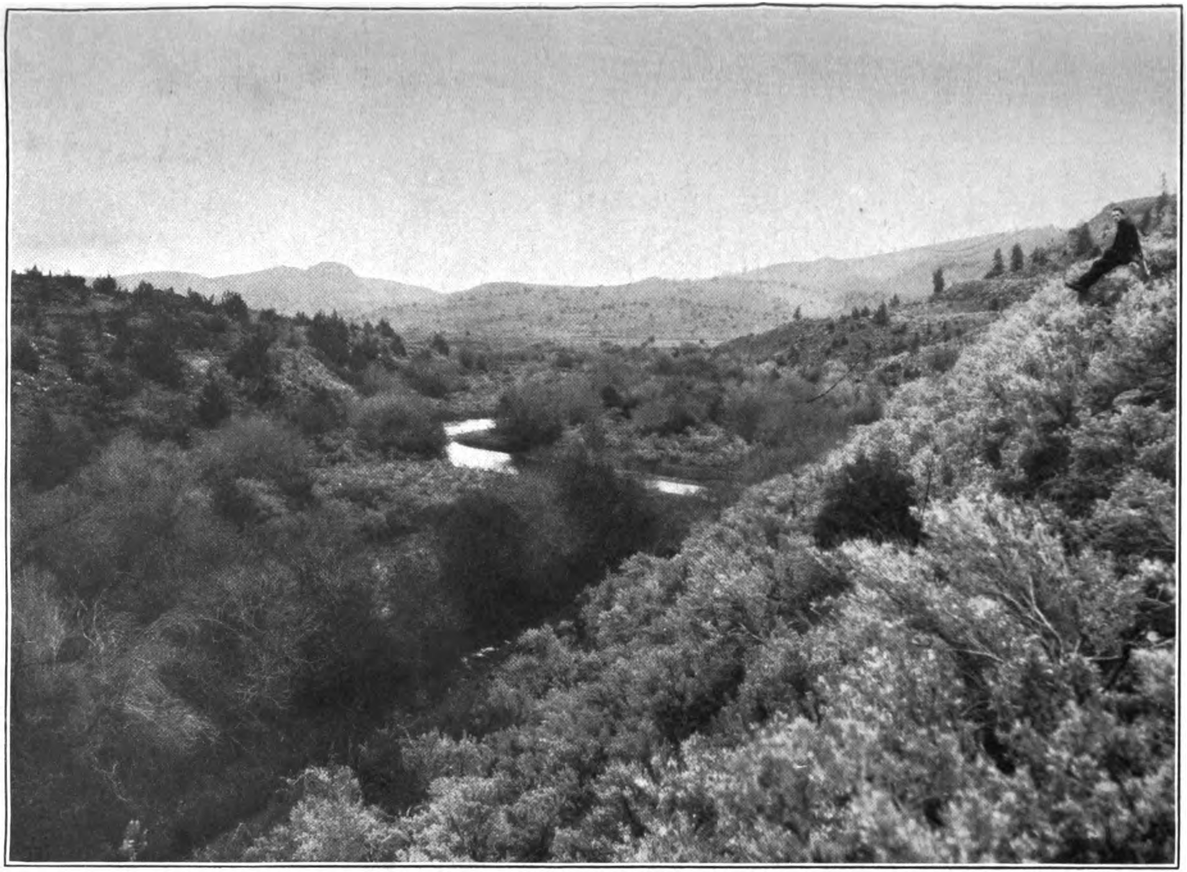
Canal-line topography was developed by plane-table traverse line, tying in with section corners for horizontal control and running from known elevation to known elevation in order to check the elevations of intervening points.

A rough classification of all the lands under consideration was made by cruising along each section line and to or through the center of each section, noting the character of each 40-acre tract in specially prepared land classification books; at the same time a rough topography of the area was sketched with the aid of a hand level, using contour intervals of 10 feet. It is believed that the results obtained are sufficiently accurate for the purposes of this investigation.

Cruised topography, thus based on hand-level work, is shown on maps in broken lines, while plane-table topography along canal location is shown in solid lines. See Plate No. 27.

Topography of Ochoco Reservoir site was developed by plane-table survey on a scale of 1,000 feet to 1 inch, with horizontal control based on plane-table triangulation, and vertical control carried up from the U. S. Geological Survey bench mark at Prineville. Dam-site topography was developed on a scale of 100 feet to 1 inch.

Reservoir topography is shown on Plate No. 30 and dam-site topography, including the location of test borings, is shown on Plate No. 32.



OCHOCO DAM SITE, LOOKING EAST.

TEST BORINGS, OCHOCO DAM SITE.

Diamond drill equipment was on hand, but as no rock was encountered no diamond bits were used. The equipment was used on some of the holes to obtain dry samples of a very tough clay.

The holes were put down for the greater part by wash boring. The process used is about as follows:

A short length of 3-inch steel flush-joint casing is set a few inches in the ground and into this there is inserted a length of rod with a chopping bit on the lower end, which is connected to the derrick rope and by hose to the force pump. Large pipe tongs are then clamped to both the casing and the rod. Water is forced through the rod and as the material is washed out of the casing, the latter is turned by the pipe tongs and gradually settles into the ground.

When a hard stratum is reached a small charge of dynamite is usually lowered to the bottom of the hole and fired after the casing has been raised a few feet. This breaks up the material so that it can be pulverized and washed out.

Careful measurements are kept so that the relative position of the bottom of the casing and drill rods is always known. Dry samples are taken with a sample bit every few feet in depth and particular attention is paid to water losses in the holes.

Detailed topography of the dam site taken after drilling work was done indicates that a dam site somewhat better than the one on which the borings were made is located about 400 feet below. The latter site was adopted for the present plans.

Following are records of test borings made:

Hole No. 1. Surface elevation, 3,015.6 feet.

Depth in feet.
0 -10. Large cobblestones, gravel, and some sand.
Water lost above 10.
10 -47. Rusty colored clay.
All water returned.
47 -49. Sand.
49 -53. Sand and a few small pebbles.
53 -68. Sand, a few small pebbles, and some clay.
Water lost slowly from 47 to 68.
Time, October 6 to 8.

Hole No. 2. Surface elevation, 3,018.2.

0 -12½. Sand and gravel, with some cobblestones 3½ to 9 inches diameter.
Water lost slowly to 12½.
12½-46½. Rusty-colored clay.
Water returned 12½-46½.
46½-50. Fine sand, with small pebbles.
50 -54. Indurated sand or soft sandstone.
Water only partly returned 46½-54.
54 -60½. Clay with sand and pebbles.
Water returns, 54 to 60½.
Time, October 6 to 9.

Depth in feet. Hole No. 3. Surface elevation, 3,020.2 feet.

0– 5. Soil.
5–18. Gravel, sand, and broken rock.
18–21. Clay, sand, and pebbles.
21–23. Coarse sand, hard packed. This sand is water-tight.
23–60. Clay and grit.
60–61. Blue clay.
61–68. Clay and grit.
Water returns 18 to 68.
Time, October 8 to 14.

Hole No. 4. Surface elevation, 3,020.4 feet.

0 –11. Sand and pebbles.
Water lost 0 to 11.
11 –25½. Clay and grit.
25½–27. Fine to coarse sand.
Water returns in this sand.
27 –45½. Clay and grit.
45½–46½. Blue clay.
46½–49½. Brown clay and grit.
49½–52½. Blue and brown clays.
52½–58½. Brown and blue clays with grit.
58½–62½. Brown clay and grit, with some pebbles.
62½–70. Blue clay and grit.
Water returns 11 to 70.
Time, October 9 to 15.

Hole No. 5. Surface elevation, 3,079.3 feet.

0– 8. Bowlder, sand, and earth slide.
8–11. Fine, soft sand.
11–33. Sand, with hard streaks at intervals.
33–36. A few bowlders and earth or sand.
36–38. Yellow clay, with a few pebbles.
38–42. Yellow clay and pebbles.
42–47. Basalt-rock ledge.
From 0–42 water lost.
From 42 to 47 estimated water-tight.

NOTE.—At 47 a cavity or large seam was struck, about 25 feet deep and extending obliquely down from bottom of bore hole, indicating proximity to edge of a ledge.

Hole No. 6. Surface elevation, 3,034.8 feet.

0– 5. Top soil volcanic ash. Holds water.
5–18. Sand from fine to coarse, with small cobbles.
Some water losses.
18–31. Coarse and fine sand, with some clay.
Water returns.
Time, October 15 to 19.

NOTE.—This hole is on bank of river, a half mile upstream from dam line.

SOILS AND AGRICULTURAL SURVEY.

The following chapter has been prepared by W. L. Powers, assistant professor of irrigation and drainage, department of agronomy, Oregon Agricultural College, from a preliminary survey made by him in March, 1915:

Description of area.—The Ochoco project includes the valley land n the north side of the Crooked and Ochoco Rivers for a distance of everal miles above and below Prineville, together with bench lands n the north side of the valley known as "Poverty Flat" and the 'Rye grass" country. About three-fourths of the project is bench land and about one-fourth valley land. The valley land is almost entirely of alluvial character, with a slight amount of wind deposit in the surface soil. The bench land is also of sedimentary character underneath, wash gravel being encountered at a moderate depth over most of the area. The surface soil has been affected somewhat by wind action, and near the butte and foothills there is a small amount of colluvial material. The mean elevation of the valley land is about 2,850 feet and that of the bench land about 2,925 feet above sea level. The valley land has a slope of from 10 to 20 feet to the mile and the bench land an average slope of perhaps 25 or 30 feet per mile. The bench land slopes to the southwest. The valley and bench lands are both surrounded by high hills.

Climate.—Due to its elevation and the higher land surrounding, the area included in this project has a rather short growing season. In the valley lands the average growing season between killing frosts is from 10 weeks to 3 months, with light frosts liable to occur in any month. The bench lands have a little longer season, ranging from 10 weeks to 4 months, between severe frosts. Air drainage of the bench land is only fair and of the bottom land is rather poor. A moderate amount of fodder corn can be grown successfully in more favored portions of the bench land and potatoes can be grown on most of the bottom lands, though they are subject to some injury by frost. Rainfall over the area will average very nearly 10 inches per year. There is slightly less than 10 inches in the vicinity of Prineville. The annual rainfall increases slightly at higher elevations toward the hills.

Agricultural conditions.—Much of the bottom land on the proposed Ochoco project was natural meadow when settlement of the land began. The grasses were used for pasture or cut for winter feed by the early stockmen. The more readily irrigable valley land was taken up over 40 years ago and has been partly cultivated for nearly a generation. The manure from feed lots has been largely wasted. It is used to some extent for irrigation dams and borders. Natural meadows of blue joint, red top, salt grass, wire grass, and other grasses produce from 1 to 3 tons of hay, besides some pasture, and are valued about the same as the naturally drained bottom land with flood-water rights. There are some very old alfalfa meadows. This crop yields from 1½ to 4 tons per acre with the flood-water rights. Three tons would be a good average yield. Grain yields well on the bottom lands; rye is used in the more frosty portions of the bottom for hay; oats and barley yield from 25 to 70 bushels per acre, and wheat and rye from 15 to 40 bushels per acre; the yields of potatoes vary from 75 to 200 bushels per acre.

The principal source of profit in the past has been hay, sheep, and beef cattle. High prices for beef in 1911 and 1912 and the diminishing range has caused stockmen to give more attention to raising their feeders and in several instances to turn their attention to dairying. There is still some unoccupied Willamette Valley and Cascade Mountain military road grant land in the river bottom.

From interviews with 10 farmers on the bottom land, it appears that the average holdings run about 400 acres per farm and about 220 acres per farm are irrigated. The land with the flood-water right is held at from $60 to $125 per acre. Clearing consists of removing large sage and willows and the average cost is about $5.50 per acre. The average capital invested per farm, as given in statements by the farmers, is $39,000 and the average net profit per farm represents slightly less than 4 per cent on this investment. It is believed that smaller acreages, more thoroughly utilized, would give a higher per cent of profit.

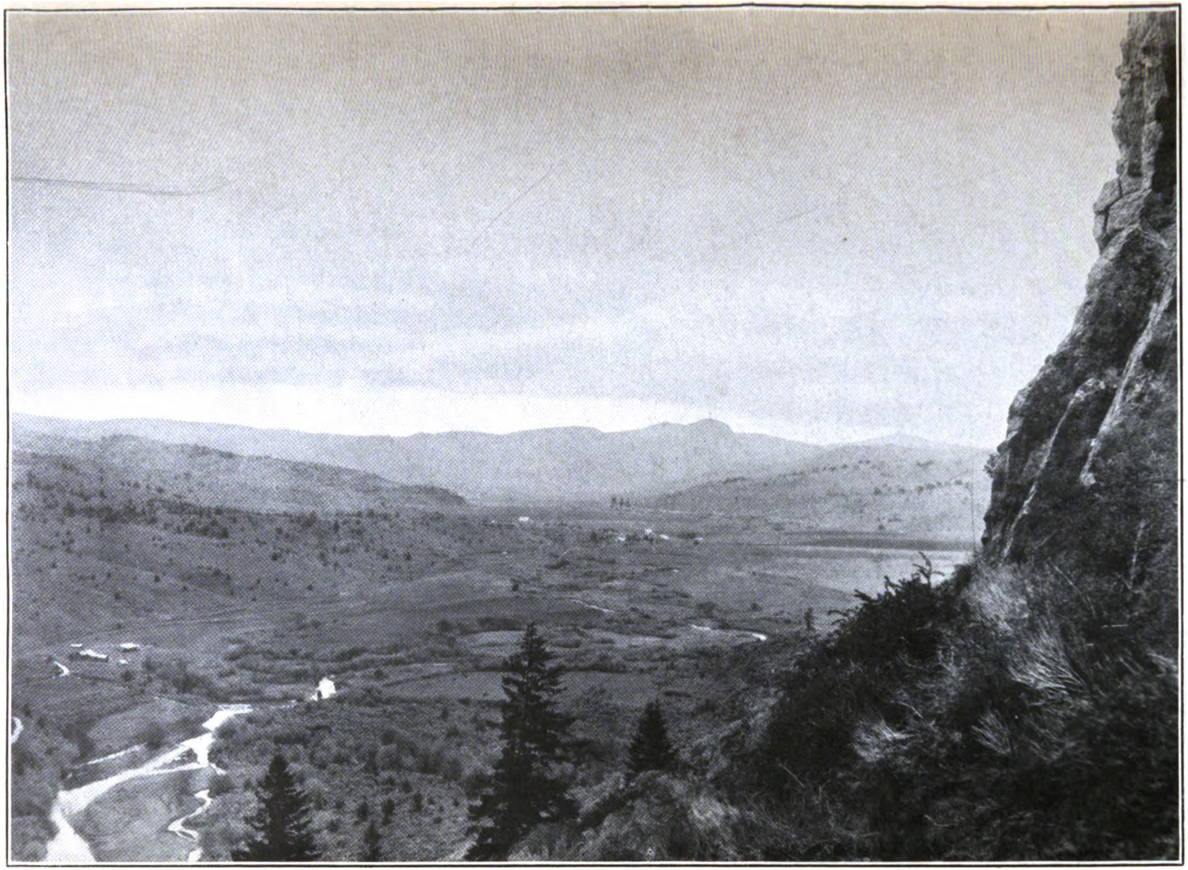
The bench land, particularly west of McKay Creek, afforded some summer range for the early stockmen. The native vegetation was mainly bunch grass, rye grass, common sage, and a few scattering junipers. Cultivation of the bench lands began as much as 16 years ago, and most of the level lying portions of the bench have been under cultivation from 7 to 10 years. About two-thirds of the bench land is in cultivation on the dry-farm plan, so that about half the cultivated area produces a light crop each second year. A few hundred acres have been given an irrigation by flood water the last few seasons.

The dry farms range from one-half to three-quarters of a section in area and summer fallowing is quite commonly practiced. Rye and wheat yield 1 ton of hay or about 15 bushels of grain per acre. The yield of oats and barley ranges from 20 to 25 bushels per acre and potatoes yield from 60 to 100 bushels per acre. Profits are small and uncertain on the main areas where the dry-farm plan is followed, and it is doubtful if the sandier portions can be profitably employed for dry farming.

SOILS.

The soils of the Ochoco project fall naturally into two groups, namely, the valley soils and the upland soils.

The valley soils are mainly alluvial deposits laid down by the streams and derived mainly from the weathering of basaltic rocks, which abound in the district and form the bulk of the underlying material. The valley soils have been more affected by water and are darker in color, contain a little more humus, and are generally of greater depth than the upland soils.



OCHOCO RESERVOIR SITE, LOOKING EAST FROM ABOVE DAM SITE.

The upland soils are also partly formed by water action. There evidence of water activity in the substrata under most of the ench land, wash gravel being encountered at moderate depth. It ppears that the water from the streams or enlargement of the reams covered a large part of this bench land at some earlier period. he surface of the material has been reworked by wind, and near arnes Butte some colluvial material has contributed to the present oil. A layer of volcanic ash occurs in the subsurface above the ash gravel in places.

The soils of the area as a whole are light and friable and fairly asy to cultivate. Their adaptability to irrigation depends largely pon their depth, drainage, and topography. The following table ives the names and extent of each of the soil types found in the choco project.

AREA OF DIFFERENT SOILS.

	Area, acres.	Per cent.
alley:		
Dark fine sandy loam	3,200	16.0
Black silt loam	1,500	7.5
Fine sand	700	3.5
Upland:		
Medium sandy loam	6,060	30.3
Medium sandy loam, heavy phase	4,740	23.7
Medium sandy loam, gravelly phase	2,500	12.5
Medium to fine sand	1,000	5.0
Fine sandy loam	300	1.5
Total	20,000	100.0

Valley soils.—The soils of the valley floor are classified into three types, which collectively embrace about one-fourth of the area of the project.

Dark fine sandy loam.—The prevailing type of soil on the bottom land is a dark, fine, sandy loam. It extends from near the rim rock or break to the steep bed of the river, and occupies an elevation of several feet above the water table. The type of soil varies in texture from fine sand to silt loam and is generally dark brown in color. The native vegetation of this soil type was large common sage and small amounts of various native grasses. Along the streams native willows were found. The soils generally have good depth, and over a large part of the area there is as much as 10 feet. In places the substratum is rather sandy or gravelly, and usually the color and texture of the surface soil is carried down to exceptionally good depth. The subsurface usually contains a layer of alkali or "rainfall hardpan." The soil is fairly free working, with slightly heavy tendencies, and is rather imperfectly drained, so that it contains more or less alkali. Irrigation has not been employed regularly or for periods of time sufficiently long to dissolve the rainfall hardpan or alkali hardpan. In a good many places these thin layers in the subsoil interfere with drainage and help to cause water-logging and accumulation of soluble salts at the surface. In some places, where the land has been thoroughly and regularly irrigated, this hardpan has been dissolved. There are also rather sandy layers in the subsoil that will permit successful underdrainage. Some of the lands that are rather alkaline in character have been improved by flushing off the salt with flood water in the early spring. As this land has come under irrigation, alfalfa has been introduced and is the principal irrigated crop on this soil type. It yields two good crops a year and a third crop can be obtained where there is sufficient water supply. All kinds of small grain yield well on this type of soil. Potatoes and the hardy root crops and such hardy crops as kale or Dwarf Essex rape will do well on this type of soil, where there is air drainage and protection from heavy frosts. This type of soil appears to have a relatively large supply of plant food and is capable of rather intensive development. It can be readily drained where drainage is needed and is well suited to irrigation purposes.

The mechanical analyses of the chief soil types on this project were made by Prof. C. V. Ruzek, of the department of agronomy, Oregon Agricultural College. The analysis of a sample of fine sandy loam is given in the following table:

Mechanical analysis of dark fine sandy loam.

[Location: S. ½, sec. 35, T. 14 S., R. 16 E.]

No.	Description.	Coarse gravel.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.	Humus.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
2	Surface	0.6	1.74	11.52	7.00	14.42	21.62	36.87	7.13	1.21

Black silt loam.—About 1,500 acres of the lower portions of the river valley above and below Prineville have been naturally subirrigated and so continually affected by water that they now contain a large amount of vegetable matter and appear almost black in color. The inorganic material contained in the soil has been deposited mainly in still water and is of a fine texture, so that the soil classifies as a "silt loam." In places there is a clay loam layer in the subsoil. Just above Barnes Butte the valley is narrow and the floor of the valley is springy, so that the land there is continually wet. The presence of this water has been a further aid to complete decomposition of mineral material and the formation of a fine-textured soil. Nearly all of this type of soil is in natural meadow grasses, such as salt grass, red top, blue joint, and wire grass. The soil is of good depth, although in places there are hard layers in the subsoil which seem to aid in maintaining the wet condition. These meadows are enerally alkaline in their reaction and poorly drained. In their resent condition they are well adapted to grasses, but little effort as been made to drain them. They produce good yields of hay and ave a high carrying capacity when used for pasture land. They re valued about the same as the surrounding well-drained land or the ine sandy loam. If well drained and irrigation water were controlled, they would be well adapted to root crops and grain crops in addition to grasses. The lighter portions of this soil type might also be utilized for alfalfa. The texture is heavier than the ideal for irrigation purposes. This land needs drainage more than it needs further irrigation. It is apparently well supplied with plant food.

Fine sand.—Small areas of fine sand occur in the slope near rim rock at the edges of the valley. The largest area of fine sand is found south and east of the fair grounds near Prineville. There are many small spots which are sandy, several of them too small to map. The sandy spots in the valley floor are usually the higher spots. The subsoil to this type usually is of somewhat heavier texture, so that the amount of irrigation water required is not excessive. The surface soil, especially until it has been under irrigation for a few years, is subject to wind erosion and requires rather careful handling. Use of a light nurse crop in seeding and the disking in of a light dressing of manure help to control the blowing. This soil appears to be moderately fertile, is of a rather brown color, and well adapted to irrigation. Irrigation is necessary for the proper utilization of this type of land. Care will be necessary to control erosion by wind and irrigation water, and a short rotation should be practiced. There is more pumiceous sand in the soil, especially close to the buttes, and the fertility is probably not above average.

Fine sandy loam.—This occurs in limited quantity near the foothills at the northwest edge of the project. The sagebrush is large on this area, the texture is almost ideal for irrigation farming at this altitude, and there is apparently a good supply of plant food. The soil lies well and is 3 feet or over in depth. It is regarded as very good soil for irrigation purposes.

Upland soils.—The upland soils of this project are comparatively uniform and but three types were recognized.

Medium sandy loam.—The most extensive type of soil on the project and the prevailing type of soil on the upland is medium sandy loam. This class is typically developed in the rye grass district, which embraces the west portion of the bench land. The soil is of a light brown to gray color and is free-working, with a slightly heavier texture in the subsoil. The native vegetation was common sage, with a small amount of yellow sage in the shallower places on the breaks and flats. There is a small amount of scattering juniper on land that is still in the native state. This soil is fairly free-working and of almost ideal texture for irrigation purposes. It has a comparatively good depth, ranging from 1½ to 3½ feet or more, and has comparatively good capacity for usable soil moisture. Most of th area of this type lies favorably for the distribution of irrigati water.

Drainage is generally good, and the land is apparently fairly free o alkali. Small alkali spots appear in well-defined draws, but it i believed that these can be readily controlled. The soil has bee proven well adapted to all kinds of small grains,, and, with irrigatio the main portion of it will be suitable for alfalfa and the hardy roo crops and potatoes and field peas. The shallow parts of the lan are more suitable for clover and timothy in rotation with grain an cultivated crops. The mechanical analysis of this type of soil is as follows:

Mechanical analysis of medium sandy loam.

[Location: S. ½ Sec. 9, T. 14 S., R. 15 E.]

No.	Description.	Coarse gravel.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.	Humus.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6................	Surface....	8.8	3.41	13.03	9.77	21.81	29.51	17.59	5.84	0.57

Heavy medium sandy loam.—The bench land east of McKay Creek and especially east of Barnes Butte is rather sandy on the surface and contains sand clay in the subsoil. This subsoil stratum is rather hard in the virgin state and there has not been enough rainfall to soften it. Irrigation will tend to soften the subsoil and to deepen this soil. As the texture is such as to be naturally mulched on the surface and still retain moisture well in the subsoil, this heavy phase of the bench land will require but moderate amounts of irrigation water. The soil is very similar to the medium sandy loam already described except for this heavier subsoil. The topography is probably a little more broken. There is perhaps a slightly larger amount of juniper where the land is in a virgin state. Mechanical analyses of the surface and subsoil are given in the following table:

Mechanical analyses of heavy medium sandy loam and sandy clay loam.

[Location: N. ½ Sec. 35, T. 14 S., R. 16 E.]

MEDIUM SANDY LOAM.

No.	Description.	Coarse gravel.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.	Humus.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1-a..............	Surface....	0.00	1.94	13.14	15.58	30.36	18.18	15.16	6.57	0.64
SANDY CLAY LOAM.										
1-b............	Subsoil....	1.00	3.02	10.90	11.58	20.56	13.88	14.94	24.26	....

Gravelly phase.—There are about 2,500 acres of land along the reaks and gulches that is rather rough, steep, and shallow. It ontains more gravel and in places more clay, the top soil being partly roded. No attempt was made to map these areas which are only or 8 rods wide along some of the chief benches. They are shown by he contour map and include most of the land with a slope of more than 10 feet per 100. Most of this area can well be excluded from the present project.

Medium to fine sand.—This occurs around Barnes Butte and near rim rock at the west end of the bench land. The surface soil is rather undulating, with some rather steep slopes. It is believed that irrigation will be necessary to the profitable utilization of this soil.

Soil fertility.—Soils of this project have produced good crops where suitable moisture conditions have been maintained. The chief type of soil on the project was submitted to the chemistry department, where it was analyzed by Mr. R. F. Beard. Commenting upon the determinations, Prof. H. V. Tartar, station chemist, said:

> Sample No. 6 was analyzed for its content of nitrogen, phosphorous, and potassium, three of the essential plant foods which are liable to be deficient in soils. The results of the analysis are as follows:
>
> | | Per cent. |
> |---|---|
> | Total potash (K_2O) | 1.51 |
> | Total phosphorus (P_2O_5) | .186 |
> | Total nitrogen | .086 |
>
> The amount of potash present is very good, comparing very favorably with most of our Oregon soils. The quantity of phosphorus is average; other conditions being favorable, the phosphorus is evidently present in quantity ample for plant growth. The amount of nitrogen is somewhat low, this being characteristic of many eastern Oregon soils. Most of our western Oregon soils contain at least 0.20 per cent of nitrogen. On the other hand, the soils of the more arid regions contain in many instances much less than this amount. We have found some productive soils in this region with only as much nitrogen as this sample contains. The nitrogen in these soils seems to be in a very available form.

IRRIGATION.

Water has been diverted and applied to the valley lands by numerous farmers' ditches for a great many years. Recently a ditch has been constructed to apply flood water to a part of the bench land. The common method of irrigation has been contour flooding, the laterals and furrows being laid out on the ridges or across the slope to lead the water out over the higher places and allow it to flood the surface of the field. Alfalfa is the chief irrigated crop where water has been provided and will easily continue to be the chief crop under irrigation. The soils of this project take up water readily, and the gentle sloping bottom lands are well adapted to the border method of irrigation for alfalfa. By this method the field to be irrigated is laid off in long, narrow strips separated by low, broad borders 6 to 8 feet wide and not over 8 or 10 inches high. These strips should be about

3 rods wide and may be from 10 to 20 rods long, depending on the slope and character of the soil. The soil between these borders should be made smooth and be leveled to one plane. There should be a uniform moderate slope from the upper to the lower end of the check. Water admitted at the upper end spreads over the surface of the inclosure until it reaches the lower end.

The corrugation or furrow method of irrigation should be used for applying water to most of the bench lands. Head ditches should be provided about 440 feet apart and the water diverted from these into the small corrugations by means of lath tubes. With proper conservation of spring rainfall, grain should usually require but one irrigation on this project and potatoes will probably do best with two light irrigations rather than a single heavy one. About three irrigations should be sufficient for alfalfa.

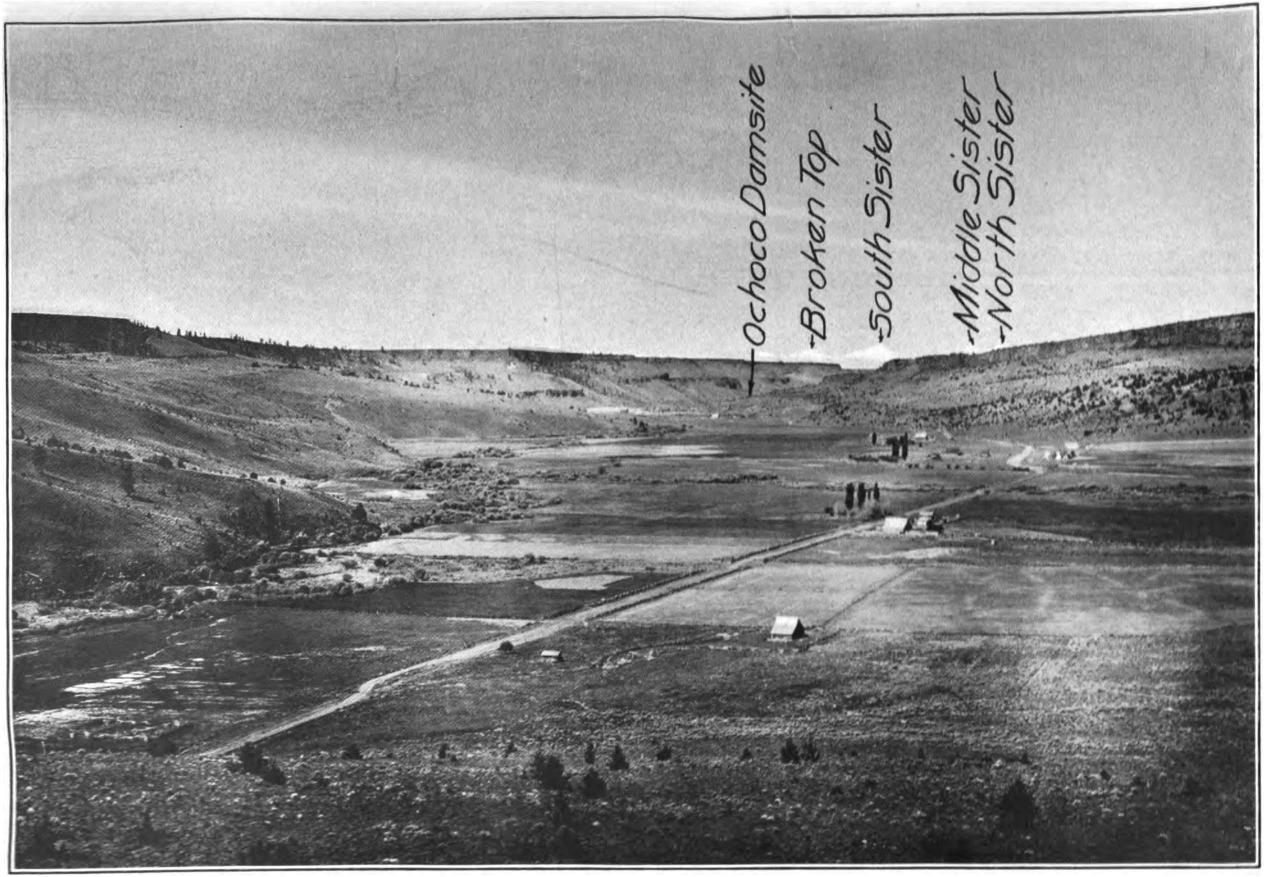
If the practice of the best farmers in the district is followed, 1½ to 1¾ feet in depth over an acre per season should be reasonable as an allowance of water for bench lands, and 1¾ to 2 acre-feet should be a reasonable amount for bottom land, provided some diversity of cropping is practiced.

Excluding the steep breaks and stream beds, there is little land on the proposed project having a slope of less than 10 feet per 100 that is not suitable for irrigation purposes.

✓ **Alkali.**—While alkali crusts and salt grass appear on the bottom land about Prineville and in a few draws on the bench, it is believed the alkali problem can be readily solved by draining the areas affected, which constitute a minor part of the project. Representative samples of the bench land subsoil and hardpan, and also representative bottom-land samples, were submitted to the station chemists to determine whether alkali was commonly present in the main areas of the project in sufficient amount to render likely any serious trouble after years of irrigation. Analyses by Mr. R. F. Beard and comments on them by Prof. H. V. Tartar, chemist, which follow, indicate that alkali troubles should not interfere greatly with the success of the project.

Sample No.	Description.	Section.	Township.	Range.	Per cent alkali.
2–a	Surface bottom land along Ochoco Creek	S. ½ of 35	14 S.	16 E.	0.018
2–b	Subsoil	S. ½ of 35	14 S.	16 E.	.024
6	Subsoil from bench land	S. ½ of 9	14 S.	15 E.	.022
X	Hardpan (subsoil bench land)	SE. ¼ of 30.	14 S.	16 E.	.022

These results show that the amount of soluble alkali salts in the samples is not large, not greatly exceeding two one-hundredths of 1 per cent in any instance. This quantity of soluble salts is not sufficient, in my opinion, to interfere with the growth of agricultural crops.



OCHOCO RESERVOIR SITE, LOOKING WEST FROM NEAR EAST END OF RESERVOIR.

Drainage.—Most of the bench land on this project has sufficiently od depth and slope to insure good drainage. There are numerous ell-defined draws that will carry excess water away. Probably less an 8 per cent of the bench land will ever be troubled by poor rainage if irrigation is practiced. Nearly all of the fine sand in the alley floor has good drainage, and the natural meadows can be rought into a higher state of production by having the water conrolled by drainage.

The dark fine sandy loam in the valley floor contains an excessive mount of alkali in various places, and as irrigation is applied to the ench land it will become more and more important to provide the eavier portions and lower lying portions of this type of soil with rainage. Much of it is underlaid with one or more layers of hardan but these can be dissolved by careful use of irrigation water nd drainage will make it possible to more readily soften these hard ubstrata and to control the alkali. Surface drainage in places can e secured at present, so that alkali salts may be flushed off by using lood water in the winter season. Drainage ditches are as necessary o a complete irrigation system as are the irrigation ditches, unless there is good natural underdrainage. A system of outlet ditches will be needed for this type of soil in the vicinity of Prineville and below. Probably one-half of this type of soil will require some drainage. With good surface outlets provided, it is believed that little underdrainage will be required. The distance to the stream bed in most cases is less than a mile and at the stream bed a good outlet can be secured. The cost of outlet drainage systems will not exceed five to eight dollars per acre for the land affected. Fairly thorough underdrainage may be required to control excess water and alkali on the steep land in the river bottom just above Barnes Butte. A large amount of water rises in this vicinity and it may be best to leave the worst part of this land in permanent natural meadow. Wells are obtained over the whole project at depths ranging from 10 to 40 feet and one or two artesian flows have been obtained at greater depth.

Best types of irrigation agriculture for the project.—As already indicated, the type of farming in the valley during the past has been hay and live stock. Little use has been made of farmyard manure in the valley and almost no attention given to crop rotation and maintenance of fertility. With irrigation, dairying and hog raising should become leading industries of these lands. As the use of irrigation grows it will be more necessary to practice rotation of crops and the application of manures to the land, in order to return fertilizer removed by the large annual yields that will be obtained, and to build up and maintain the water capacity and available fertility of the soil.

On the bench lands, light crops of grain have been produced each second year. Little attention has been given to a permanent system of agriculture. Irrigation would make it possible to raise legume crops such as alfalfa, clover, and field peas, and these could be raised in rotation with grain and cultivated crops. Considering present transportation facilities, it would seem most practical to feed these crops to dairy and meat-producing animals that could be marketed in condensed form, and the fertility left on the land. A reasonable farm unit under irrigation for conditions obtaining on the project would be 60 to 80 acres.

Probable value of irrigation.—The chief area of soil on the project is sandy loam bench land which at present is partly dry-farmed. Irrigation would make it possible to raise large crops annually, where now only light crops are raised each second year, on land where the dry-farm plan is followed. It would make possible the production of legumes and the maintenance and feeding of live stock, which would permit a rotation of crops, better control of weeds through intensive farming, and the establishment of a more permanent system of agriculture. With irrigation, most of this bench land would yield 3 to 3½ tons of alfalfa. The better portions of it should yield as much as 4 tons of alfalfa per acre with careful handling. This crop would easily be the leading crop for some years to come and its value, fed to live stock, should determine what it is possible to realize from these bench lands under irrigation.

The soil on the bench land of this project is a little coarser but has better depth and drainage than that of the north unit of the Deschutes project. There is a slight disadvantage in climatic conditions and transportation facilities. The juniper land is free from rocks as compared with the west unit of the Deschutes project, while the soil has a little finer texture and greater depth.

The bottom land appears productive enough to justify the expense required for reclamation by irrigation and drainage. With a complete water right the lands under cultivation in the valley would be brought into a much higher state of production and much fertile land that is now idle would also be made productive. With such a water right the bottom land should yield 3½ to 4 tons of alfalfa per season. The productiveness and even topography make the valley attractive for irrigation purposes.

The lands of the project are all within a few miles of a substantial town, with a creamery and other industries related to agriculture already established. There is much outside summer range in the surrounding mountains. It is believed that the project offers a comparatively safe field for irrigation development and is worth the estimated cost if interest charges do not exceed 3 per cent.

These surveys were made possible by arrangement with the college uthorities. Professor J. E. Larson, of the college, accompanied the writer during most of the field work in connection with this report.

WATER SUPPLY, OCHOCO CREEK.

Ochoco Creek, one of the largest tributaries of Crooked River, rises in the Blue Mountains east of Prineville. It is an intermittent stream, having practically no run-off in summer and about half of its total yearly run-off during the months of March and April. The drainage area is about 300 square miles, the upper part being forested, while the lower part consists of steep rolling hills and the fertile bottom lands of the valley proper.

Following are monthly discharges of Ochoco Creek from records of the United States Geological Survey:

Discharge records.—The records of discharge for Ochoco Creek are meager and somewhat scattering. They include but one complete climatic year, but furnish fairly complete data for estimating three other years.

Ochoco Creek at Elliott's ranch (about 6 miles east of Prineville.)

	Discharge.			Total run-off.
	Maximum.	Minimum.	Mean.	
1908–9.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
November	22	....	10	595
December	32	6	10.3	633
January	306	6	107	6,580
February	440	60	113	6,280
March	276	45	135	8,300
April	248	148	181	10,800
May	170	45	97.5	6,000
June	75	18	32	1,900
July	17	....	5.4	332
August	1.5	....	.87	54
September	1.5	....	.45	27
The period	....	....	....	41,500
1909–10.				
October	0.5	....	0.13	8
November	1,050	....	109	6,490
December	387	83	158	9,720
1909–10.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
January	422	38	143	8,790
February	387	52	110	6,110
March	608	262	431	26,500
April	234	67	148	8,810
The period	....	....	....	66,400
1914–15.				
November 23–30	19	17	18.8	298
December	15	....	7.61	468
January	15	....	9.13	561
February	60	15	30.8	1,710
March	200	23	117	7,190
April	290	6	99.1	5,900
May	45	6	22.1	1,360
June	19	1	6.17	367
The period	....	....	....	17,900

Ochoco Creek at Prineville.

	Discharge.			Total run-off.
	Maximum.	Minimum.	Mean.	
1913–14.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
December 15–31	23	9	10.2	343
January	122	28	76.4	4,700
February	207	23	91.9	5,100
March	415	112	292	18,000
April	280	55	159	9,460
May	46	....	5.02	309
1913–14.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
June 1–25	7	0.2	1.01	51.5
The period	....	....	....	38,000
1915.				
March 7–31	154	16	78.6	3,900
April	149	....	58.7	3,490

Elliott's Ditch at intake (diverts above station on Ochoco Creek.)

	Discharge.			Total run-off.
	Maximum.	Minimum.	Mean.	
1908.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
November	2.8	....	0.75	45
1909.				
April	8.5	....	2.61	155
May	7.5	....	4.30	264
June	5.9	....	1.48	88.1
July	2.7	....	.72	44.3
August	1.5	....	.09	3.1
September	....	....	....	....
The period	....	....	....	600
October	.9	....	.37	22.8
November	2.2	....	1.00	59.5
1910.				
April	6.0	....	1.91	114
The period	....	....	....	196

	Discharge.			Tot run-o
	Maximum.	Minimum.	Mean.	
1914–15.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-f*
October	....	....	1.0	61
November	....	....	1.0	59
December	....	....	.8	49
January	....	....	1.0	61
February	3.2	....	1.23	68
March	3.2	....	.64	39
April	8.7	....	2.94	175
May	6.6	....	4.85	298
June	7.9	....	4.75	283
The period	....	....	....	1,100

Table Land Ditch near intake (diverts above station on Ochoco Creek.)

	Discharge.			Total run-off.
	Maximum.	Minimum.	Mean.	
1915.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
February 24–28	20	18	19.4	192
March	20	....	12	738
April	14	12	13.9	827
May	14	12	13.4	824
June	14	0.2	3.71	221
The period	....	....	....	2,800

Estimated yearly discharge, 1903 to 1915.—The following discussion of water-supply records of Ochoco Creek and probable discharges for the past 12 years, has been prepared by Fred F. Henshaw, district engineer, United States Geological Survey, in charge of the cooperative stream gaging work in Oregon.

A gaging station was established on Ochoco Creek at the proposed dam site by the United States Geological Survey, on October 29, 1908; also one on Elliott's ditch which diverts above the gage on the creek. These were maintained until April 30, 1910. They were reestablished October 26, 1914, and a station was installed on the Table Land ditch, which was constructed in 1912, and which also diverts above the station on the creek. Records were kept on Ochoco Creek at the bridge in Prineville, below all diversions, from December 15, 1913, to June 25, 1914; also during March and April, 1915. During the two latter months the recorded run-off was approximately 3,000 acre-feet per month less than that at the dam site about 7 miles above. It has been assumed that the same rate of depletion held for about 3 months in 1914, a year in which the high water lasted longer than in 1915.

The recorded and estimated discharges of Ochoco Creek at the dam site during the three years of record, are as follows:

	Acre-feet.
For 1908–9:	
Recorded run-off of Ochoco Creek, Nov. 1–Sept. 30	41,500
Recorded run-off of Elliott ditch, Nov. 1–Sept. 30	600
Estimated run-off of creek and ditch, October, 1908	300
Total	42,400
For 1909–10:	
Recorded run-off of Ochoco Creek, Oct. 1–Apr. 30	66,400
Recorded run-off of Elliott ditch	196
Estimated run-off of creek and ditch, May 1–Sept. 30	5,000
Total	71,600
For 1913–14:	
Recorded run-off of Ochoco Creek at Prineville Bridge, Dec. 15–June 25	38,000
Estimated run-off Oct. 1–Dec. 14	1,000
Estimated net diversion of water between dam site and station	10,000
Total	49,000
For 1914–15:	
Recorded run-off Nov. 23–June 30—	
Ochoco Creek	17,900
Table Land ditch	2,800
Elliott ditch	1,100
Estimated run-off Oct. 1–Nov. 23 and July 1–Sept. 30	200
Total	22,000

It is thus possible to approximate closely the available water supply for the proposed Ochoco project for four seasons, of which one (1914–15) will prove the lowest in many years, according to information at present available. The other three are more nearly normal years.

Records of discharge are available for many streams in eastern Oregon for the last 12 years, beginning in 1903. In order to study the records of these streams, and to afford a means of comparing them with the Ochoco, there have been listed in the accompanying table the yearly run-offs, so far as observed, for all stations in eastern Oregon, also for Columbia River at The Dalles. Two columns of figures are given for each station, the first column being the total annual run-off in thousands of acre-feet, and the second column indicating the order of magnitude of the total run-off at each station for the respective years listed, No. 1 being the highest and No. 12 the lowest year.

Yearly run-off in thousands of acre-feet for streams in Oregon, 1903–1915, indicatin order of magnitude for different years.

	Station.											
	Columbia River at The Dalles.		Owyhee River at Owyhee (including canal).		Malheur River near Namorf.		Powder River at Salisbury.		Silvies River near Burns.		Umatilla River at Gibbon.	
Drainage area..	237,000		11,100		....		230		940		35	
Year.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.
1903–4..........	176,000	1	1,160	5	753	1	146	1	298	1	451	1
1904–5..........	101,000	11	392	11	383	8	55.5	11	77.4	10	184	11
1905–6..........	114,000	10	1,080	7	488	3	79	9	140	6	275	
1906–7..........	166,000	2	1,380	2	....	4	116	4	....	2	350	
1907–8..........	143,000	5	420	10	....	11	86.3	7	....	9	295	
1908–9..........	139,000	6	1,270	3	357	6	75.8	10	97.2	8	281	
1909–10..........	154,000	3	1,470	1	499	2	120	3	152	5	377	
1910–11..........	136,000	7	1,160	6	262	9	79.7	8	73	11	249	10
1911–12..........	133,000	9	1,240	4	286	7	127	2	172	3	....	....
1912–13..........	154,000	4	606	9	224	10	111	5	118	7	....	....
1913–14..........	135,000	8	979	8	380	5	110	6	162	4	....	....
1914–15..........	....	12	330	12	146	12	....	12	....	12	....	....
Mean....	138,000	....	957	....	358	....	96.4	....	137	....	315	....

	Station.											
	Umatilla River at Yoakum.		John Day River at Dayville (including South Fork).		John Day River at McDonald.		East Fork of Deschutes River at Allen's ranch.		Crooked River near Prineville.		Ochoco Creek near Prineville.	
Drainage area..	1,200		1,600		7,800		920		1,990		300	
Year.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.	Run-off.	No.
1903–4..........	786	1	....	....	2,500	1	....	....	....	....	....	....
1904–5..........	235	11	....	....	928	11	165	8	....	....	....	....
1905–6..........	522	6	....	....	1,430	7	140	11	....	....	....	....
1906–7..........	658	3	....	....	2,100	3	258	3	....	....	....	....
1907–8..........	418	8	....	....	1,010	8	184	6	....	....	....	....
1908–9..........	351	9	269	9	992	9	178	7	189	9	42.4	8
1909–10..........	532	5	320	6	1,500	6	279	2	375	3	71.6	2
1910–11..........	303	10	241	10	961	10	161	9	204	8	....	....
1911–12..........	718	2	547	2	2,410	2	196	4	328	4	....	....
1912–13..........	652	4	338	4	1,770	4	191	5	238	7	....	....
1913–14..........	430	7	326	5	1,520	5	158	10	284	5	49	5
1914–15..........	220	12	....	12	632	12	110	12	....	12	22	12
Mean....	486	....	329	...	1,480	....	193	....	265	....	48.3	....

The values for 1914–15 have been computed for 5 stations up to April 30, and the probable run-offs for the remaining five months, estimated, in order to give a yearly total. The means for the 12 years, 1903–4 to 1914–15, have been computed, using estimated values for years of missing records.

In the following table yearly values of departures from the 12-year mean for the 12 stations, expressed in terms of per cent departure from the mean, have been arranged in decreasing order of magnitude. The records for any station, when thus arranged, form a series, the terms of which, if numerous enough, vary in accordance with the nathematical law of probability. The first or highest year, which in he case of all streams except the Owyhee, occurred in 1903–4, was or Malheur River, 110 per cent above the mean; 117 per cent above or the Silvies, ranging down to 43 per cent above for Umatilla River t Gibbon; the general average, omitting the Columbia, being 73 per cent above the mean. The sixth year was the most nearly normal, averaging 3 per cent above the mean, but for individual streams varied from 21 per cent above to 6 per cent below. The lowest year in all cases is 1914–15, as estimated; and it is altogether improbable that such abnormally large precipitation can occur after May 1 as to bring the run-off up to that of the next lowest year.

Per cent departures from the mean of each of 11 eastern Oregon streams shown in order of decreasing magnitude for each stream.

Year in order of magnitude.	Columbia River at The Dalles.	Owyhee River at Owyhee.	Malheur River near Namorf.	Powder River at Salisbury.	Silvies River near Burns.	Umatilla River at Gibbon.	Umatilla River at Yoakum.	John Day River at Dayville.	John Day River at McDonald.	East Fork at Allen's ranch.	Crooked River near Prineville.
1	+ 27	+ 54	+ 110	+ 52	+ 117	+ 43	+ 62	....	....	....	....
2	+ 20	+ 44	+ 39	+ 32	....	....	+ 48	+ 46	+ 63	+ 44	....
3	+ 12	+ 33	+ 36	+ 24	+ 25	+ 20	+ 35	....	+ 42	+ 34	+ 41
4	+ 12	+ 30	....	+ 20	+ 18	....	+ 34	+ 3	+ 20	+ 3	+ 24
5	+ 4	+ 21	+ 6	+ 15	+ 11	+ 11	+ 9	– 1	+ 3	– 1	+ 7
6	+ 1	+ 21	– 0	+ 14	+ 2	– 6	+ 7	– 3	+ 1	– 5	....
7	– 1	+ 13	– 20	– 10	– 14	....	– 12	....	– 3	– 8	– 10
8	– 2	+ 2	– 21	– 17	– 29	– 11	– 14	....	– 32	– 15	– 23
9	– 4	– 37	– 27	– 18	....	– 13	– 28	– 18	– 33	– 16	– 29
10	– 17	– 56	– 37	– 21	– 44	– 21	– 38	– 27	– 35	– 18	....
11	– 27	– 59	....	– 42	– 47	– 42	– 52	....	– 37	– 27	....
12	....	– 66	– 59	....	....	....	– 55	....	– 57	– 43	....

The position, in order of magnitude, of the four years for which records were obtained on Ochoco Creek, may be approximated by comparison with other streams. For the year 1908–9, the positions of the other nine streams (omitting Columbia and Owyhee Rivers) were sixth and seventh once, eighth twice, ninth four times, and tenth once, giving a mean of 8+.

For the year 1913–14 the positions were fourth once, fifth four times, sixth, seventh, and tenth once each, giving a mean of 6–, but it was fifth on the stream most nearly comparable with the Ochoco and has been so considered.

Similarly 1909–10 has been considered the second year, and 1914–15 is, in all cases, twelfth.

On plate 45 the information listed in the tables has been shown in the form of diagrams (see Paper No. 1308, Transactions American Society of Civil Engineers, Vol. LXXVII, p. 1539, by Allen Hazen), the values for the highest, second highest years, etc., for each station being platted on the same vertical line and a mean line drawn through the point. The distance between the vertical lines is greater near the ends of the diagram than in the center, as the variation between successive values is greatest nearest the extremes.

The data for Columbia River have not been platted, as conditions in its drainage basin are hardly comparable with those of Ochoco Creek. In the lower diagram the run-off of Ochoco Creek for the 4 years recorded has been platted on the vertical lines on which they appear to belong, considering the position of these same years on other streams.

The probable 12-year mean for Ochoco has been determined as follows: The average departure from the 12-year mean as shown by the line in the upper diagram for the second, fifth, eighth, and twelfth years of the period is −4¼ per cent—i. e., one-quarter of +45 per cent, +10 per cent, −16 per cent, −56 per cent. The average run-off for the 4 years during which records exist, and which have been estimated to correspond to the second, fifth, eighth, and twelfth years of the 12-year period, is 46,250 acre-feet and is considered comparable with the average of the departures of these years, which from the upper diagram has been shown to be 4¼ per cent below the 12-year mean. The 12-year mean is in this manner estimated to be 48,300 acre-feet.. A line giving the same variations from the mean as the line in the upper part of the diagram has been drawn to show probable values for other years of the series during which no observations were made. Thus the observed and estimated values for the past 12 years of Ochoco Creek at the dam site arranged in order of magnitude are as follows:

Yearly run-off in acre-feet of Ochoco Creek at dam site near Prineville.

	Acre-feet.
First (highest) year	86,000
Second year, 1909–10	71,600
Third year	63,000
Fourth year	57,000
Fifth year, 1913–14	49,000
Sixth year	48,000
Seventh year	44,000
Eighth year, 1908–9	42,400
Ninth year	37,000
Tenth year	32,000
Eleventh year	28,000
Twelfth year, 1914–15	22,000
Mean	48,300

There is considerable uncertainty in the left, or upper, portion of the curve, as 1909–10 may have been the third instead of second year in order of magnitude, while the first, or highest, year may be expected to be as much as twice the mean, or at least 100,000 acre-feet, if the variation of the Ochoco is similar to that of Malheur and Silvies Rivers.

With regard to probable discharge prior to 1903, there are few reliable data. Records covering 7 years on Umatilla River at Yoakum, 1896 to 1903, show an average about 27 per cent greater than for 1903–1915. Five years of records on Owyhee River, 890–1896, show 30 per cent greater, and on Columbia River at The Dalles the mean for 1878 to 1903 is 16 per cent greater than for the ast 12 years. On the other hand, the records on Malheur River at Vale in the nineties show less than the later average, but these ecords are subject to fully as great uncertainty as any of the others. The weight of evidence seems to indicate that the mean for the last 12 years is lower than a mean based on a longer period of records.

IRRIGATING SEASON.

The length of irrigating season for any project depends upon conditions of climatic and seasonal rainfall. In the northern parts of the United States it is generally considered to extend from about May 1 to the first week of September, the extreme period commencing as early as the frost is out of the ground and there is warmth enough to stimulate plant growth, and ending in some localities only when pasture ceases to grow.

The averages of the records of monthly and annual temperature and precipitation for Prineville for the years 1897–1913, inclusive, given in the following table, are from the United States Weather Bureau records:

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Temperature (degrees)	33.2	36.1	40.7	46.5	53.2	58.2	65.0	65.0	56.7	49.1	38.4	35.8	48.2
Precipitation (inches)	0.91	1.08	0.82	0.81	0.92	0.80	0.34	0.28	0.65	0.64	1.09	1.00	9.34

Following is a tabulation of the temperature and precipitation for the year 1906. This year has been selected both because the records are complete and because the mean temperature and the mean precipitation for the year coincide very closely with the average for the 17 years of record.

1906	Temperature.			Frost.	Hail.	Thunderstorm.	Precipitation (mean).
	Maximum.	Minimum.	Mean.				
January	51	8	35.2				0.75
February	60	16	36.2				.36
March	65	−1	35.2				1.25
April	85	20	45.8				.44
May	86	26	52.0	16th, 17th	25th.	9th, 25th	1.23
June	90	33	55.2			15th, 25th	2.10
July	98	42	70.6			5 days	.81
August	95	34	64.1			11th, 12th	.10
September	89	27	58.7	10th, 11th			.55
October	83	15	48.3	13 times			.51
November	68	8	37.4				.72
December	55	9	37.0				.53
Annual	98	−1	48.0				9.35

The greatest range in temperature of record at Prineville is fr 119°, July, 1898, to —29°, January, 1909. The average range, ho ever, is from about 0° winter to 100° in summer. The avera range of frosts is from the latter part of August to the early part June, although light frosts have been known to occur as late as Ju 15 and as early as August 2. It is a well-known fact that owing the dryness of the air in this locality temperatures of 32° or even or 5° lower do not always result in the formation of frost, and t hardy varieties of vegetation are seldom materially injured by lo summer temperatures.

The Ochoco project is within the arid region, the mean annu rainfall for the period of record being 9.34 inches, with a range from 7.10 inches in 1911 to 13.31 inches in 1907.

In considering the Ochoco project it has seemed desirable to allow for the first application of water in May and to make this comparatively small on account of the frequent occurrence of frosts as late as June. A small allowance of water has been estimated for September. In general this will be a final irrigation for pasture crops. No allowance has been made for any use of water after September for domestic supply or for irrigation. Domestic supply can generally be obtained from wells of practicable depth.

Late fall irrigation is not considered for the reason that there is little or no advantage to be gained in the matter of storage by so doing, and it is generally recognized that such irrigation tends to prevent proper aeration of the soil.

The percentage distribution of water by months during the irrigating season is assumed as follows:

May	15
June	27
July	31
August	20
September	7
Total	100

EVAPORATION AND SEEPAGE LOSSES.

The difference between the water actually stored and that required on the land is the sum of losses due to evaporation from reservoir and canal surfaces, seepage loss from reservoir, and seepage losses in canals and distributaries.

Evaporation losses from water surfaces have been the subject of considerable study. Most of these studues have been made from pans located on the ground, and the results obtained are now thought to be higher than actually occur from surfaces of large bodies of water. The conditions governing rate of evaporation are those of temperature, altitude, wind movements, and the nature of the body of water. That is, the evaporation is greater from a broad, shallow ody of water than from one of considerable depth. Evaporation osses, according to more recent investigations, vary from about 3 eet in depth per annum in the higher altitudes to about 6 or 7 feet in he lower and arid sections.

A maximum annual evaporation of 48 inches in depth has been ssumed for Ochoco reservoir and the following table shows assumed monthly rates in inches of depth:

January	0.45	August	8.30
February	1.15	September	5.30
March	3.00	October	2.30
April	5.95	November	0.90
May	6.45	December	0.45
June	6.30		
July	7.25	Annual	48.00

Evaporation from the water surface of canals has been neglected here as it is comparatively small. For example, evaporation during the irrigating season would be about 3 feet in depth, and in a canal 20 miles long and 10 feet wide at the water surface, this would amount to about 70 acre-feet or a loss of 0.2 per cent which is negligible.

Reservoir seepage.—The probable amount of seepage from a reservoir is difficult to estimate even approximately except by actual experiment. It depends primarily on the geological or physical character of the underlying strata which can not be determined satisfactorily even with most exhaustive examination by test holes or pits.

Records from various storage basins show seepage losses from practically nothing at East Park Reservoir, Cal., to as high as 85 per cent from Deer Flat Reservoir during the first year of its use.

It is of interest to note, however, that the losses from this latter reservoir have gradually decreased until in the sixth year they amounted to less than 30 per cent.

It is believed, from records of borings at Ochoco dam site (see Plate No. 32) and Hole No. 6 in the reservoir site, a half mile above the dam site, that the subsoil of Ochoco reservoir consists largely of clay and that seepage losses will be comparatively small. Hole No. 6 was put down about a half mile above the dam site to determine the character of material in the bottom as affecting seepage losses. While this hole did not penetrate a clay stratum as in the case of the holes at the dam site, nevertheless the sand at the bottom was very compact and intermixed with clay, and there was no evidence of any loss of water by seepage when work was stopped.

Springs between the dam site and Prineville give evidence that considerable of whatever seepage there may be from the proposed reservoir will be brought to the surface and made available for the irrigation of bottom lands. It has been assumed for this estimate that the seepage from the reservoir, completely lost to this project, will be 10 per cent of the total reservoir capacity.

Canal seepage.—Seepage losses from canals are generally expressed in terms of percentage of flow lost per mile, or as the loss in 24 hours in terms of cubic feet per square foot of wetted area.

The latter method has been used in this estimate.

Results of investigations by Bark on seepage losses from canals in Idaho, 1913–14 biennial report of State engineer of Idaho, show that "canals in average South Idaho soil, which is a medium clay loam, should be designed to withstand a loss of from 0.5 to 1.5 cubic feet per square foot of canal bed, per 24 hours; that 0.5 cubic feet per square foot per day is a safe basis for clay soils that are relatively impervious, about 1 cubic foot per day for medium soils, and from 1.5 to 2 cubic feet per square foot per day is a safe basis for somewhat pervious soils."

The soils of the Ochoco project are considered about equivalent to the medium clay soils of Idaho in relation to their resistance to losses by seepage. The soil is light and fine textured, and it is believed canal losses will be comparatively small, due to natural silting of the bottom. The loss by seepage from canals in this estimate has therefore been assumed at 1 cubic foot per day per square foot of wetted area.

Seepage losses in concrete-lined canals are almost negligible. Experiments have shown that they do not exceed 1 inch in depth per square foot of wetted area per 24 hours, and this figure has been used in the estimate.

Seepage loss in the main canal has been estimated as follows: Mile 0 to mile 8.95 is a concrete lined section, and seepage loss assumed as 1 inch in depth per square foot of wetted area per 24 hours. Mile 8.95 to mile 21 is an earth section, and seepage loss assumed as 12 inches in depth per square foot of wetted area per 24 hours. The rate of seepage for July is 11.4 second-feet, or a loss of about 0.074 per cent per mile for concrete lined sections, and 1.5 per cent per mile for the earth section at mile 8.95, increasing to 4.5 per cent per mile at mile 21. The total seepage for July is 700 acre-feet. As the flow in July is 0.31 of the total, the total loss from seepage in the main canal if assumed to be proportionate to the amount of water being carried, will be 700÷0.31=2,260 acre-feet.

The minimum capacity of laterals to 40-acre tracts has been assumed as 10 second-feet. With rotation and a high irrigation head, seepage in the lateral system can be reduced materially below that for the continual flow method of delivery. The total length of laterals up to the 40-acre tracts is approximately 452,900 feet, but several trials have shown that the average continual working length is about 0.35 of the actual length, or 158,400 feet. Assuming a seepage loss of 12-inch depth per 24 hours over a wetted perimeter which averages about 7 square feet per foot length of canal, the loss would be about

30 acre-feet during July. When a section of a lateral is not working will dry out, and the loss on first applying water will be greater an for laterals having a continual flow. In order to allow for is loss the further assumption is made of a 12-inch absorption of ater for each of two irrigations over the remaining 0.65 of the total ngth of lateral, or approximately 90 acre-feet.

The total losses by seepage and absorption in the lateral system, nus estimated and expressed in acre-feet, are: 780+90=870 acre-eet for July, and 870÷0.31=2,800 acre-feet for the irrigation eason.

RELATION OF PRESENT WATER RIGHTS TO PROJECT.

The recent adjudication of water rights of Crooked River and its ributaries indicates that rights to the use of the waters of Ochoco nd McKay Creeks for irrigation of lands under the proposed Ochoco roject have been granted for about 5,400 acres of land. This pro-ides for irrigation during the spring months only, for the greater art of the land, as no storage has as yet been undertaken and there s little or no run-off during the summer months.

It is impracticable to go into relative values of the different rights n this estimate, and only an approximate idea of the amount of water required by all these lands can be obtained from the data available. The only record of stream flow at the proposed dam site during the irrigating season was obtained in 1909. Partial records for the years 1912 and 1914 were obtained at Prineville, but there is no record of the amount of water diverted between Prineville and the dam site. The run-off for 1909 seems to have been a little below the average for the streams in the State, but deductions as to the value of present water rights have been made, using the data obtained at that time as a basis for the estimate.

Of the 5,400 acres of land having water rights, about 1,000 acres are located on McKay Creek. There are no records of flow of this stream, and it is therefore difficult to arrive at a satisfactory conclusion as to the probable amount of water they would need, but for the purposes of this estimate it is considered that it would be the same as that for lands having rights on Ochoco Creek.

According to the adjudication, the water users are allowed one-eightieth of a second-foot per acre continual flow, or about 0.75 acre-feet, per acre per month.

The monthly flow of Ochoco Creek in acre-feet for the irrigation season of 1909 was:

May	6,000
June	1,900
July	332
August	54
September	27

At 0.75 acre-feet per acre per month the number of acres with adjudicated rights that could have been irrigated would be:

May	5,400+
June	2,540
July	450
August	70
September	40

The number of acres requiring water would then be:

May	0
June	2,860
July	4,950
August	5,330
September	5,360

The economic duty will be shown to be 1.85 acre-feet per gross acre delivered to 40-acre tracts. Therefore the water applied to these lands would be:

June	2,860×1.85×0.27=1,430 acre-feet.
July	4,950×1.85×0.31=2,840 acre-feet.
August	5,330×1.85×0.20=1,970 acre-feet.
September	5,360×1.85×0.07= 690 acre-feet.
Total	6,930 acre-feet.

The proportionate amount of water required would be 6,930÷(5,400×1.85)=0.693, or 69.3 per cent.

Since there are certain springs rising between the dam site and Prineville which furnish irrigation waters to land in summer, and because of the uncertainty as to the use of a single year which is probably not an average in run-off, the percentage has been reduced to 60.

The 5,400 acres having rights on Ochoco and McKay Creeks, averaged as a whole, would require only 0.6 as much water as would be required by the other lands. The equivalent average area having full water rights on this assumption would be 5,400×0.6=3,240 acres, or, say, 3,200 acres.

IRRIGATION DEVELOPMENT PROPOSED.

It is proposed to store the water of Ochoco Creek in Ochoco Reservoir and to serve approximately 17,700 acres of irrigable lands, of which 12,300 acres are located on the bench and 5,400 acres, requiring partial water rights, are mostly on the bottom adjacent to Ochoco Creek, McKay Creek, and Crooked River.

Water available.—It was shown that the 5,400 acres of lands at present having water rights would require approximately 0.6 of a water right from Ochoco storage. Then 0.4 of a water right for this land will have to be deducted from the run-off at the dam site in order to arrive at the average amount available for storage. Assuming a diversion duty of as much as 2.2 acre-feet per acre, the deduction would be 5,400×0.4×2.2=4,700 acre-feet.

The bottom lands in Ochoco Reservoir site have water rights for about 500 acres which would revert to the project. Assuming an annual diversion use of 2 acre-feet per acre, the run-off at the dam site would be increased by about 1,000 acre-feet. The average annual run-off of Ochoco Creek then for the past 12 years available for storage (see "Water Supply") would be 48,300 − 4,700 + 1,000 = 44,600 acre-feet.

With these assumptions the yearly run-off of Ochoco Creek in acre-feet available for storage in order of decreasing magnitude would be:

	Acre-feet.
First (highest) year	82,300
Second year, 1909–10	67,900
Third year	59,300
Fourth year	53,300
Fifth year, 1913–14	45,300
Sixth year	44,300
Seventh year	40,300
Eighth year	38,700
Ninth year	33,300
Tenth year	28,300
Eleventh year	24,300
Twelfth year, 1914–15	18,300
Mean	44,600

It is evident that for the best economic development of the land a considerable shortage of water must at times be borne. Any provision for decreasing this shortage by providing reservoir capacity sufficient to hold the water over from a wet year is considered impracticable on account of the very high cost of storage.

A reservoir capacity of 40,000 acre-feet has been assumed as the maximum economic storage.

The table of yearly run-off available for storage for the last 12 years shows that there would have been appreciable shortages during 4 years, amounting, respectively, to 16.7, 29.2, 39.2, and 54.2 per cent.

A shortage of as much as one-third need not affect the yield materially and can be offset largely by increased cultivation of the soil, particularly where the water supply is entirely stored and available when it can be used to best advantage.

The large shortage for the present climatic year 1914–15 is by no means to be considered as liable to occur as often as once in 12 years. The records of the Columbia River at The Dalles, which extend back to 1878, show that the low run-off of the present year is probably comparable with that occurring in 1899, which is the lowest year of record.

It is therefore believed that with a storage of 40,000 acre-feet considerable shortages will not occur oftener than an average of once in 10 years and serious shortages not oftener than an average of once in 25 years.

Duty of water.—Water duty is an expression of the ratio between a given quantity of water and the area of crop which it will mature. The units of measurement of water in common use now are the acre-foot and the second-foot. Second-foot is a term used to express a rate of flow of fluids equal to 1 cubic foot per second of time. The miner's inch is also an expression for rate of flow, subject to varying interpretations of value. In Oregon the courts have ruled that a miner's inch is equal to one-fortieth of a second-foot. One acre-foot equals the amount of water that will cover 1 acre of ground 1 foot in depth, or 43,560 cubic feet. This unit is applied in speaking of large volumes, such as reservoir storage, where the cubic foot is too small an amount to convey a conception of that volume.

Probably no one consideration has so much influence in the success of a project as the selection of the proper duty of water. On it depends the amount of storage necessary, the sizes of the main canal and distributaries, and also to a great extent the future productivity of the land. Recent investigations have shown that with an abundant supply of water there is a tendency on the part of the irrigator to use more than is necessary, with the result that the land is frequently impoverished by leaching out of valuable constituents or that it becomes water-logged or alkaline.

The duty of water for maximum returns depends upon the climate, the nature of the soil, the rate of evaporation, the kind and diversification of crops grown, and, above all, upon the skill of the irrigator.

The duty for maximum returns, however, is not always the economic duty, this latter being dependent on cost of storage and distribution of water, as well as on the amount of water available.

It has been shown that the maximum economic storage which can be assumed for Ochoco Reservoir is about 40,000 acre-feet. With a reservoir of this capacity the average area of the water surface is about 575 acres.

The total evaporation from the reservoir surface will then be 2,300 acre-feet per year, using the 4-foot depth previously assumed as the annual rate of evaporation. The sum of unavoidable losses is then as follows:

	Acre-feet.
Seepage from reservoir 10 per cent	4,000
Evaporation	2,300
Seepage from main canal [1]	2,260
Seepage and absorption in lateral system [1]	2,800
Total	11,360

The net amount remaining for application on the land is then 40,000 acre-feet minus 11,360 acre-feet, or 28,640 acre-feet. The gross area of 17,700 acres consists of about 12,300 acres of bench land which will require full water rights and 5,400 acres of bottom lands requiring partial water rights, which, as previously estimated, are equivalent to 3,200 acres having full water rights.

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[1] See "Evaporation and seepage losses."

There is therefore available from this water supply $\frac{28{,}640}{12{,}300+3{,}200}=$ 1.85 acre-feet per acre of irrigable land, delivered to 40-acre tracts.

In the paper "Duty of Water Investigations" by Don H. Bark, engineer in charge of irrigation investigations for the Department of Agriculture, appearing in the 1913–14 biennial report of the State engineer of Idaho, the results are given of some very extended and careful observations covering a period of 4 years, 1910–1913, inclusive, on 529 individual tracts in the Snake River Valley at elevations of from 2,114 to 4,950 feet.

As this report is not readily available, some of the results of the investigations are given here:

Summary of depths of water, applied by months to 171 fields of grain and alfalfa on medium clay and sandy loam soils (Bark).

[Altitudes ranging from 2,400 to 5,000 feet. Seasons of 1910, 1911, 1912, and 1913.]

Season.	Number of plots.	April.		May.	June.	July.	August.	September 1–15.	Total for season.
		1–15.	16–30.						
119 fields of grain:									
1910	31			0.3210	0.6000	0.5460	0.0780		1.5450
1911	30			.0270	.6540	.4780	.0100		1.1690
1912	25				.9420	.6550	.0460		1.6430
1913	33		0.0392	.2062	.5434	.5941	.2268		1.6097
Average			.0098	.1385	.6849	.5683	.0902		1.4917
Per cent of total			.66	9.28	45.91	38.10	6.05		100.00
52 fields of alfalfa:									
1910	15	0.0600	.0210	.5540	.7390	.6530	.6070	0.0650	2.6990
1911	13		.0350	.4930	.2930	.9130	.6970	.2480	2.6790
1912	11			.4910	.5030	.6210	.6080	.0380	2.2610
1913	13			.8627	.2284	.7422	.3854	.0175	2.2362
Average		.0150	.0140	.6002	.4408	.7323	.5744	.0921	2.4688
Per cent of total		.61	.57	24.31	17.86	29.66	23.26	3.73	100.00

Summary of depths of water in feet, applied by months to 171 selected fields of grain and alfalfa on medium clay and sandy loam soils (Bark).

[Altitudes ranging from 2,400 to 5,000 feet. Seasons of 1910, 1911, 1912, and 1913.]

Crop.	Season.	Number of plots.	April.		May.	June.	July.	August.	September 1–15.	Total for season.
			1–15.	16–30.						
Alfalfa	1910	15	0.0600	0.0210	0.5540	0.7390	0.6530	0.6070	0.0650	2.6990
Grain	1910	31			.3210	.6000	.5460	.0780		1.5450
Alfalfa	1911	13		.0350	.4930	.2930	.9130	.6970	.2480	2.6790
Grain	1911	30			.0270	.6540	.4780	.0100		1.1690
Alfalfa	1912	11			.4910	.5030	.6210	.6080	.0380	2.2610
Grain	1912	25				.9420	.6550	.0460		1.6430
Alfalfa	1913	13			.8627	.2284	.7422	.3854	.0175	2.2362
Grain	1913	33		.0392	.2062	.5434	.5941	.2268		1.6097
Average			.0075	.0119	.3693	.5628	.6504	.3323	.0460	1.9802
Per cent of total			.38	.60	18.65	28.42	32.85	16.78	2.32	100.00

Table showing comparative areas devoted to different crops (Bark).

District.	Year.	Hay and pasture.		Grain, potatoes, and orchard.		Total acres.
		Area acres.	Per cent of total.	Area acres.	Per cent of total.	
Twin Falls South side project	1912	70,043	47.55	77,266	52.45	147,30
Twin Falls South Side project	1913	67,115	44.95	82,196	55.05	149,31
Seven Boise Valley projects	1911	[1] 26,253	[1] 59.75	17,684	40.25	43,9
Six Boise Valley projects	1912	24,492	57.90	17,804	42.10	42,2
Total		187,903		194,950		382,8
Per cent of total			49.08		50.92	

[1] This area and percentage was somewhat above normal on account of the comparatively large amoun of bottom land that was seeded to pasture under some of these canals.

Some extracts from Bark's summarization are as follows:

The duty of water depends upon a variety of factors which are, in the apparent order of their importance: Character of soil and subsoil, fertility of soil, climatic conditions, diversification of farm crops, use of rotation, preparation of the land, kind of crop, fall plowing, and other factors of lesser importance.

The following factors and conditions tend to decrease the duty: Porous soil, infertile soil, cheap water, careless use, poorly prepared land, small irrigation heads, poorly constructed, leaky ditches, continuous flow method of delivery, lack of cultivation, large acreages of alfalfa and pasture, and other crops with large water requirements.

The following factors and conditions tend to increase the duty: Deep soil of fine texture, an underlying stratum of hardpan, expensive water, careful, skillful use, well leveled land, large irrigation heads, short runs, use of rotation systems, diversification of crops, well constructed irrigation systems with small transmission losses, fall plowing and intensive surface cultivation, large acreages of winter grain, cultivated crops and orchard, and other crops of low water requirements.

The amount of water required by a project depends upon: The duty of water at the land, losses in reservoirs where water is stored, transmission losses from the point of diversion to the land to be irrigated, and the proportion of a project that is ultimately irrigated.

Fertile soils require less water for the production of the same crop than infertile soils.

A tight, impervious soil that roots can penetrate increases the duty.

More water is required where porous subsoils exist.

Gravelly soils should invariably be irrigated by flooding large heads of water short distances.

Cultivated crops, all other things being equal, require less water than uncultivated crops as loss from evaporation can be reduced by thorough surface cultivation.

Fall plowing tends to materially increase production and decrease water requirements.

Grains and cultivated crops in general require less irrigation water than the other common crops of south Idaho.

Winter grains require less water than spring grains.

The time of application has a decided effect upon the yield of grain.

Diversification of crops greatly increases the duty.

Very little water is required for a project either earlier than May or later than August.

The average length of the irrigation season for alfalfa for the four years of the investigation was 97.6 days and 42.5 days for grain.

The need for water is not constant during the season for projects with diversified crops. About 1 per cent of the season's supply is required during April, 18 per cent

> uring May, 28 per cent during June, 32 per cent during July, 16 per cent during ugust, and about 2.5 per cent during the first half of September, after which there is ery little need for water.
>
> The use of rotation systems and large irrigation heads decreases the net amount of ater required during the season.
>
> Normal canal systems, particularly where water is inexpensive, divert far more ater than is actually required both early and late in the season.
>
> The amount of water that will produce the largest yield of a certain crop in a certain oil, is not always the economic duty.
>
> The value of land, the cost of water, the value of crops produced, and the cost of roducing them, as well as the amount of water that will produce the largest yield, ust all be taken into consideration when determining the economic duty for any roject.
>
> Sufficient water for the production of profitable and nearly maximum crops must e delivered in order that a project may be successful, but a higher duty is justified n cases where water is very valuable and land comparatively cheap, than where ater is cheap and the land is valuable.
>
> The duty for projects planted to diversified crops on the average clay loam soils of outh Idaho should be sufficient so that 2 acre-feet per acre can be retained on each rrigated acre.

Bark's experiments were carried out on tracts of an average size f 15 acres. The distance of the measuring weirs from the tracts varied from 0 to 200 yards, and it is therefore considered that the duty he recommends be used for that of water delivered at the 20-acre tracts of this project.

In placing the duty at 2 acre-feet per acre, Bark considers that an allowance of 0.25 acre-foot per acre should be made for water which will be wasted by the farmer during the year. Half of this he assumes will be picked up in canals of the lower lands, so that the duty for projects planted to diversified crops on average clay loam soils can be considered as 2.125 acre-feet per net acre delivered to 20-acre tracts.

It is not customary to figure water as delivered to less than 40-acre tracts in projects given over to production of grains and forage crops. It will be necessary then to apply a correction for seepage loss in laterals from 40-acre tracts to 20-acre tracts.

The average length of lateral would be about one-quarter of a mile. With 15,500 acres the total length of additional laterals to the 20-acre tracts would be approximately 100 miles. These laterals would be of about 5 second-feet capacity and the wetted area would be 5 square feet per foot length. Assuming two irrigations of 0.3 feet depth each during July, 5 second-feet will cover 20 acres in two 15-hour periods. The total working time then will be 30 hours, and assuming a loss of 1 cubic foot per day per square foot of wetted area the seepage will be 76 acre-feet. Absorption loss for preliminary wetting of the 100 miles of lateral twice a month, assuming a loss of 1 cubic foot per square foot of wetted area, would be 64 acre-feet, making the total loss for July 140 acre-feet in distributing from the 40 to the 20 acre tracts. As 31 per cent of the water is delivered in

July the seasonal loss would be 140 ÷ 0.31 = 452 acre-feet. This woul amount to 452 ÷ 15,500 = .03 feet depth on the land for the season.

While water-right estimates are generally made on the basis of th gross area of a project to which water can be diverted that amount o land will not actually be irrigated, as it includes roads, barnyard building sites, fence rows, ditches, etc. Bark's investigations in Idah included careful surveys of over 16,000 acres of land, for the purpos of finding the average amount of waste land. This proved to b about 8 per cent. He recommends the assumption of not more than 1 per cent waste for purposes of estimating. The amount of this wast land is always uncertain and very often runs as high as 20 per cent

If the duty is taken as 2.125 acre-feet per acre of net area at th 20-acre tracts, and the waste land at 10 per cent the duty per acre o gross area would be 1.91 acre-feet at the 20-acre tracts, or 1.94 fee at the 40-acre tracts.

It is considered justifiable to use a comparatively high duty o Ochoco project for the following reasons: (1) The water supply o Ochoco Creek is limited; (2) the cost of storage is very high, being four or five times as much as the estimated costs for reservoirs at present being investigated for other projects; (3) the lands are very fertile and of fine texture; (4) there is every evidence that the subsoil is sufficiently compact to prevent excessive loss by percolation and has sufficient slope to prevent water logging; (5) it allows the development of about the maximum amount of land that can be reached economically by gravity canal from Ochoco reservoir.

It is therefore believed that a duty of 1.85 acre-feet per acre of gross area delivered to 40-acre tracts will not differ materially from the economic duty for Ochoco project, as it allows full development of the irrigable area. It is only slightly less than the duty derived from Bark's experiments, and the difference of .09 of an acre foot per acre is amply justified by conditions stated.

Water required.—It has been assumed that all water required on the lands will be drawn from storage, during the irrigating season, as the summer flow is all appropriated by present water users. It has been impossible to make any very detailed study of this problem as records of flow are too meager. The method used and the results obtained, however, are believed to be reasonably conservative.

The monthly use of water during the irrigating season, measured at the land and expressed in feet of depth, has been assumed as follows (see Irrigation season):

	May.	June.	July.	August.	September.	Total
Per cent	15	27	31	20	7	100
Depth (feet)	0.27	0.50	0.57	0.38	0.13	1.8

With a net amount of 28,640 acre-feet, applicable at the land, he monthly use of water will be:

ay	4,300
une	7,740
uly	8,870
ugust	5,730
eptember	2,000
Total	28,640

Construction, designs.—The following estimates, while founded on good field investigation and careful office computation, are to be regarded as of a preliminary nature only, and not to be construed as indicative of any estimated costs that may be announced by the Secretary of the Interior through the public notice required by section 4 of the reclamation act of June 17, 1902 (in advance of any construction by the Government).

Attention is called to the fact that the figures given are merely the first costs or actual disbursements estimated as necessary to build the work. No allowance has been made for interest, discounts, or sinking fund.

Ochoco Dam.—The proposed location of the dam for Ochoco reservoir is about 6 miles east of Prineville where the valley narrows to a width of a few hundred feet.

The design provides for maximum storage of 40,000 acre-feet above the canal outlet, no allowance having been made for more than the actual yearly requirements. The maximum elevation of water surface or spillway crest for this storage is 3,125 feet and the area flooded is approximately 1,000 acres. The elevation of the top of the dam is 3,132 or 7 feet above the spillway crest in the reservoir.

Borings were made on the line shown on plate No. 32 before detail topography of the site was made. Later it developed that there would be some saving in cost by adopting the center line about 400 or 500 feet downstream, as a dam located at this point would require less material. Classification for cross section of the lower dam site, shown on plate No. 35, has been projected from records of borings at upper site.

Holes Nos. 1 and 2 at the dam site show that the depth of sand and gravel at those points is not greater than about 10 to 12 feet. Beneath this there is a bed of very compact and impervious clay, from 34 to 37 feet thick, and underlying the clay at these points is a stratum of sand and fine gravel. While this might furnish an outlet for some seepage water from the reservoir, it is not considered as a possible source of great loss, as the record of Hole No. 6 in the reservoir shows a compact and water-tight substratum.

Holes Nos. 3 and 4 did not run out of the clay, and this strengthens the belief that the effect of sand and gravel shown by holes Nos. 1 and

2 will not be serious. Hole No. 5 indicates that there may be som difficulty in obtaining good contact between water-tight material an bedrock or canyon walls.

Before a dam site is definitely adopted for construction it will b essential that a great many borings be made over the entire regio for several hundred feet on either side of the present line of boring

From the nature of the foundations it is evident that the onl economical type of dam is an earth embankment with a puddle cut off carried through the stratum of sand and gravel to clay or othe impervious material. It is believed that this would oppose a ver effective resistance to seepage.

The dam designed (Pl. No. 35) has an upstream slope of 3 to 1 covered with hand-placed riprap 2 feet thick. The downstrea slope is 2 to 1, covered with a foot of coarse gravel to prevent erosio by wind and rain. The upstream part of the embankment is o selected loam and clay mixture, grading to coarse gravel on th downstream face. Seepage water is given an easy outlet away fro the cut-off trench, as the material in the bottom is sand and grave Where the surface soil is impervious, drainage of the lower half of th dam will be secured by gravel-filled trenches or draintile.

Outlet to the main canal is through the tower and conduit a shown. The tower is provided with two regulating gates, each o which can be operated under full head. The conduit is placed in a trench below the dam foundations and is provided with collars to prevent the flow of seepage water along its outer surface.

Probably the most frequent cause of failure of earth embankments has been lack of sufficient spillway and resultant overtopping of the dam by flood waters. The assumption of possible maximum flood conditions for Ochoco Creek has been made from the following records of flood flows of various streams in the State, obtained from the United States Geological Survey:

Stream.	Area.	Maximum flood flow.	Second-feet per square mile.	Length of record.	Date.
	Sq. miles.	*Sec.-ft.*		*Years.*	
Bully Creek	585	6,240	10.7	9	1910
Powder River	230	[1] 1,820	7.9	11	1910
North Fork of Malheur River	436	5,910	13.5	4	1910
Silvies River	510	2,320	4.6	9	1904
South Fork of John Day River	600	2,390	4.0	6	1910
John Day River at Dayville	1,000	3,090	3.1	6	1910
Crooked River	1,990	9,080	4.6	6	1910
Chewaucan River	272	4,000	14.7	9	1909
Deep Creek, Warner Valley	260	4,950	19.0	5	1910
Ochoco Creek	300	[1] 1,500	5.0	3	1909

[1] Approximate.

Occasional cloudbursts on some of the smaller streams have probably caused greater discharges for short periods of time, but as a rule these would have very little effect on a reservoir of any size.

The flood of Willow Creek, Morrow County, in 1903, commonly spoken f as the "Heppner disaster," caused an estimated run-off of more than 00 second-feet per square mile of drainage area. This continued less han an hour, and the stream returned to normal within a few hours.

Such a flood entering Ochoco Reservoir would raise the water in he reservoir about 1 foot, and the resulting flow over this spillway would not exceed 1,000 second-feet, or a little more than 3 second-feet per square mile of drainage area.

The spillway crest for Ochoco Dam is at elevation 3125.0 and has a length of 300 feet. This allows a discharge of about 10,000 second-feet of water with 4-foot head over the crest, which is nearly 10 times the maximum recorded mean daily discharge at this point and about 7 times the estimated peak flow, or equivalent to a run-off of 33 second-feet per square mile of drainage area. This is considerably more than the maximum recorded flow in eastern Oregon, that of Deep Creek, Warner Valley, which came from a drainage area of much greater altitude, having a yearly run-off 2 or 3 times as great as that of Ochoco Creek.

With 7 feet of water over the crest of the spillway, or with water surface just at the top of the dam, the discharge would be about 24,000 second-feet, or about 80 second-feet per square mile of drainage area.

The spillway channel has been designed for a capacity of 24,000 second-feet from the intake to the point where the channel curves toward the creek. (See Plate No. 35.) From this point on the channel has a capacity of 10,000 second-feet. In case a flood greater than 10,000 second-feet should ever occur, it would not in any way endanger the dam itself, and any damage to the spillway chute and main canal flume at this point could be repaired at comparatively little expense.

At times of maximum water in the reservoir, bordering lands will be more or less affected by raising of the ground water plane. It has therefore been assumed that 100 acres above the normal high water will be required, or a total of 1,100 acres. Allowance has also been made for depreciation in value of grazing lands adjacent to farms in the flooded area.

Distributing system.—The capacity of the main canal at diversion is about 180 second feet. The first reduction in size occurs within 1½ miles of the dam, at which point about 15 per cent of the water is turned out to irrigate bottom lands east and south of Prineville.

The main canal system is designed for a duty of 1 second-foot to 108 acres at the land. (See Plate No. 31 for location.)

It is proposed to line the first 8.95 miles of canal with concrete 3 inches thick, and from this point on it will be of earth throughout.

Typical canal sections with capacities are shown on Plates Nos. 36 and 37. Classification of materials in excavation was made from surface examination only, the canal sections being comparatively shallow.

Estimated costs (17,700 acres gross).

OCHOCO DAM.

Spillway:		
Rock excavation,[1] 30,000 cubic yards, at $1	$30,000	
Earth excavation, 16,400 cubic yards, at $0.40	6,560	
Cut-off excavation, 800 cubic yards at $0.50	400	
Concrete on bottom, 1,340 cubic yards, at $8	10,720	
Concrete sides and weir, 570 cubic yards, at $10	5,700	
Concrete cut-off, 165 cubic yards, at $8	1,320	
Steel reinforcing, 25,000 pounds, at $0.06	1,500	
		$56,200
Embankment:		
Earth fill, 509,000 cubic yards, at $0.50	254,500	
Rock from spillway placed in dam, 23,700 cubic yards, at $0.25	5,920	
Rock from spillway placed for riprap, 16,300 cubic yards, at $0.50	8,150	
Earth from spillway placed in dam, 16,400 cubic yards, at $0.20	3,280	
Cut-off excavation, 14,400 cubic yards, at $0.50	7,200	
		279,050
Outlet tower and conduit:		
Concrete, 460 cubic yards, at $12	5,520	
Concrete, 36 cubic yards, at $10	360	
Concrete, 45 cubic yards, at $8	360	
Steel reinforcing, 26,000 pounds at $0.06	1,560	
Excavation, 600 cubic yards, at $1	600	
Back fill, 100 cubic yards, at $1	100	
Gates in place, 2, at $750	1,500	
By-pass valves	200	
Bridge	1,000	
		11,200
House for gate keeper	1,800	
Rebuilding 5½ miles of road	5,500	
Temporary diversion	10,000	
		17,300
		363,750
Engineering and administration, 25 per cent		90,650
Total construction		454,400

OCHOCO RESERVOIR.

Reservoir lands to elevation 3,130 or 5 feet higher than spillway crest:			
Alfalfa lands	acres	520	
Cultivated bottom lands	do	230	
Bottom lands not cleared	do	130	
Side hill grazing lands	do	220	
Total		1,100	94,000
Loss in value to grazing lands adjacent to reservoir, say			6,000
Total			100,000
Purchasing, legal, land lines, and administration			10,000
Total lands			110,000
Ochoco dam			454,400
Total reservoir			564,400

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[1] 30,000 cubic yards solid rock equals about 40,000 cubic yards in dam.

DISTRIBUTING SYSTEM.

le 0 to mile 1.5:		
Canal excavation (earth, cemented gravel, and loose rock), 15,840 cubic yards, at $0.75	$11,880	
Concrete lining, 1,420 cubic yards, at $8	11,360	
2 main canal turnouts, at $75	150	
Wasteway, measuring device, and flume over spillway chute	600	
Pipe lateral across creek, etc	445	
		$24,435
ile 1.5 to mile 3.3:		
Canal excavation, 13,400 cubic yards, at $0.20	2,680	
Concrete lining 1,745 cubic yards, at $8	13,960	
Lateral excavation, 15,510 cubic yards, at $0.15	2,330	
15-inch pipe laid and back filled, 2,500 feet, at $0.53	1,324	
5 main canal turnouts, at $75	375	
39 lateral turnouts, at $20	780	
20 lateral drops and turnouts combined, at $30	600	
31 2-foot drops, at $25	775	
1 30-foot drop	100	
1 pipe siphon under Ochoco Creek	100	
		23,024
Iile 3.3 to mile 5.3:		
Canal excavation, 14,620 cubic yards, at $0.20	2,924	
Concrete lining, 1,923 cubic yards, at $8	15,384	
Lateral excavation, 2,900 cubic yards, at $0.15	440	
4 main canal turnouts, at $75	300	
14-inch pipe laid and back filled 300 feet, at $0.47	140	
2 lateral turnouts, at $20	40	
12 lateral drops and turnouts combined, at $30	360	
48 2-foot drops, at $25	1,200	
		20,788
Mile 5.3 to mile 7:		
Canal excavation, 12,000 cubic yards, at $0.20	2,400	
Concrete lining, 1,610 cubic yards, at $8	12,880	
Lateral excavation, 15,740 cubic yards, at $0.15	2,365	
14-inch pipe laid and back filled, 6,300 feet, at $0.47	2,960	
4 main canal turnouts, at $75	300	
47 lateral turnouts, at $20	940	
6 lateral drops and turnouts combined, at $30	180	
25 2-foot drops, at $25	625	
1 30-foot drop	100	
1 siphon	600	
		23,350
Mile 7 to mile 8.25:		
Canal excavation—		
Cemented gravel, 830 cubic yards, at $1.25	1,038	
Earth, 7,470 cubic yards, at $0.20	1,494	
Concrete lining, 1,156 cubic yards, at $8	9,248	
Lateral excavation, 2,150 cubic yards, at $0.15	323	
14-inch pipe laid and back filled, 1,400 feet, at $0.47	658	
15-inch pipe laid and back filled, 1,500 feet, at $0.53	795	
4 main canal turnouts, at $60	240	
8 lateral turnouts, at $20	160	
4 lateral drops and turnouts combined, at $30	120	
11 2-foot drops, at $25	275	
		14,351

Mile 8.25 to mile 8.95:		
Canal excavation—		
Cemented gravel, 840 cubic yards, at $1.25	$1,050	
Earth, 3,360 cubic yards, at $0.20	672	
Concrete lining, 620 cubic yards, at $8	4,960	
Lateral excavation, 4,695 cubic yards, at $0.15	705	
12-inch pipe laid and backfilled, 1,600 feet, at $0.37	592	
14-inch pipe laid and backfilled, 1,400 feet, at $0.47	658	
2 main canal turnouts, at $60	120	
10 lateral turnouts, at $20	200	
14 lateral drops and turnouts combined, at $30	420	
31 2-foot drops, at $25	775	
		$10,152
Mile 8.95 to mile 10:		
Canal excavation, 8,350 cubic yards, at $0.20	1,670	
Lateral excavation, 13,820 cubic yards, at $0.15	2,072	
15-inch pipe laid and backfilled, 500 feet, at $0.53	265	
14-inch pipe laid and backfilled, 1,200 feet, at $0.47	563	
4 main canal turnouts, at $75	300	
35 lateral turnouts, at $20	700	
11 lateral drops and turnouts combined, at $30	330	
48 2-foot drops, at $25	1,200	
1 30-foot drop	100	
		7,200
Mile 10 to mile 11.12:		
Canal excavation, 8,220 cubic yards, at $0.20	1,640	
Lateral excavation, 2,600 cubic yards, at $0.15	390	
3 main canal turnouts, at $75	225	
12 lateral drops and turnouts combined, at $30	360	
39 2-foot drops, at $25	975	
1 culvert	100	
		3,690
McKay Creek grade crossing		750
Mile 11.12 to mile 13.12:		
Canal excavation—		
Cemented gravel, 2,936 cubic yards, at $1.25	3,670	
Earth, 11,744 cubic yards, at $0.20	2,350	
6 main canal turnouts, at $75	450	
		6,470
Mile 13.12 to mile 13.83:		
Canal excavation—		
Cemented gravel, 1,000 cubic yards, at $1.25	1,250	
Earth, 4,000 cubic yards, at $0.20	800	
Lateral excavation, 530 cubic yards, at $0.15	80	
14-inch pipe laid and backfilled, 1,800 feet, at $0.47	845	
15-inch pipe laid and backfilled, 900 feet, at $0.53	480	
2 main canal turnouts, at $75	150	
2 lateral turnouts, at $20	40	
2 lateral drops and turnouts combined, at $30	60	
9 2-foot drops, at $25	225	
		3,930

Mile 13.83 to mile 15.20:		
Canal excavation—		
Cemented gravel, 1,336 cubic yards, at $1.25	$1,680	
Earth, 5,350 cubic yards, at $0.20	1,070	
Lateral excavation, 8,540 cubic yards, at $0.15	1,280	
12-inch pipe laid and back filled, 400 feet, at $0.37	150	
14-inch pipe laid and back filled, 200 feet, at $0.47	95	
3 main canal turnouts, at $75	225	
19 lateral turnouts, at $20	380	
24 lateral drops and turnouts combined, at $30	720	
56 2-foot drops, at $25	1,400	
		$7,000
Mile 15.20 to mile 15.74:		
Canal excavation, 2,500 cubic yards, at $0.20	500	
15-inch pipe laid and back filled, 4,800 feet, at $0.53	2,540	
2 main canal turnouts, at $60	120	
3 lateral turnouts, at $20	60	
		3,220
Mile 15.74 to mile 16.80:		
Canal excavation, 4,650 cubic yards, at $0.20	930	
Lateral excavation, 730 cubic yards, at $0.15	110	
15-inch pipe laid and back filled, 1,800 feet, at $0.53	955	
3 main canal turnouts, at $60	180	
1 lateral turnout, at $20	20	
3 lateral turnouts and drops combined, at $30	90	
23 2-foot drops, at $25	575	
		2,860
Mile 16.80 to mile 17.45:		
Canal excavation, 2,300 cubic yards, at $0.20	460	
Lateral excavation, 5,200 cubic yards, at $0.15	780	
15-inch pipe laid and back filled, 2,000 feet, at $0.53	1,060	
2 main canal turnouts, at $60	120	
11 lateral turnouts, at $20	220	
15 lateral drops and turnouts combined, at $30	450	
32 2-foot drops, at $25	800	
1 20-foot drop	80	
		3,970
Mile 17.45 to mile 18:		
Canal excavation, 1,800 cubic yards, at $0.20	360	
Lateral excavation, 500 cubic yards, at $0.15	75	
15-inch pipe laid and back filled, 600 feet, at $0.53	320	
2 main canal turnouts, at $60	120	
1 lateral turnout, at $20	20	
3 lateral drop and turnouts combined, at $30	90	
13 2-foot drops, at $25	325	
		1,310
Mile 18 to mile 19.57:		
Canal excavation, 3,050 cubic yards, at $0.20	610	
Lateral excavation, 7,730 cubic yards, at $0.15	1,160	
14-inch pipe laid and back filled, 2,600 feet, at $0.47	1,225	
15-inch pipe laid and back filled, 1,800 feet, at $0.53	950	
6 main canal turnouts, at $50	300	
11 lateral turnouts, at $20	220	
27 lateral turnouts and drops combined, at $30	810	
73 2-foot drops, at $25	1,825	
		7,100

Mile 19.57 to mile 21:		
Canal excavation, 1,950 cubic yards, at $0.20	$390	
Lateral excavation at 240 yards, at $0.15	40	
14-inch pipe laid and backfilled, 1,000 feet, at $0.47	470	
15-inch pipe laid and backfilled, 600 feet, at $0.53	320	
6 main canal turnouts, at $40	240	
2 lateral turnouts, at $20	40	
2 lateral drops and turnouts combined, at $30	60	
		$1,560
Mile 21 to end of distributaries:		
Lateral excavation, 3,200 cubic yards, at $0.15	480	
12-inch pipe laid and backfilled, 1,000 linear feet, at $0.37	370	
14-inch pipe laid and backfilled, 3,300 feet, at $0.47	1,550	
15-inch pipe laid and backfilled, 1,500 feet, at $0.53	800	
10 lateral turnouts, at $20	200	
8 lateral drops and turnouts combined, at $30	240	
16 2-foot drops, at $25	400	
		4,040
20 small inlets, at $20	400	
20 bridges, at $60	1,200	
Right of way	5,000	
Fence (5 wire), 42 miles, at $125	5,200	
Telephone lines, 16 miles, at $250	4,000	
		15,800
Engineering and administration, 25 per cent		46,200
Total cost of distributaries		231,000
Total estimated cost of irrigating 15,500 acres:		
Storage		564,400
Canals and distributing system		231,200
Estimated cost per acre, $51.30		795,600

Drainage.—The bench lands, by reason of the character and depth of soil, good slope, and frequent draws or breaks which afford natural drainage, will probably require little artificial drainage at any time in the future. It is believed that whatever drainage may be required for these lands will be in small areas, such as is usually taken care of by the landowner, even where a general system of drainage is provided, and no provision is made either in the plans or estimates for such drainage.

Under irrigation at least a part of the bottom lands will undoubtedly require drainage (see "Soils and agricultural survey"), but as a general statement this necessity already exists at the present time. The additional irrigation proposed will without doubt increase the necessity for drainage, but it it is believed the cost will be little if any increased as a result, and no estimate for drainage of these lands has therefore been included.

Operation and maintenance.—See discussion of this subject in Deschutes project report. The Ochoco project is exceptionally compact. As the storage dam acts also as the diversion dam, the

oject is relieved of the operation and maintenance of a diversion
d head gates. The main canal from the reservoir begins to serve
nd almost at once, eliminating the necessity of maintaining a long
nal between either reservoir or diversion and lands irrigated.
his main canal is planned to be concrete lined for a considerable
stance and all structures are designed to be of concrete. It is be-
eved, therefore, that the operation and maintenance cost for the
roject will be as low as that for any of the projects now being
perated by the Reclamation Service.

By reference to the operation and maintenance cost table for
eclamation Service projects in 1912, page 140 of Deschutes project
eport, it is seen that the cost of operation and upkeep, or mainte-
ance exclusive of supplemental construction, for the smaller projects
s as low as 26 cents per acre for the Leasburg unit of the Rio Grande
roject, running up to as high as $1.27 per acre for the Okanogan
roject.

Probably 60 to 75 cents per acre would be a fair estimate of the cost
f operation and maintenance, including small supplemental construc-
ion from time to time, such as lining occasional laterals, constructing
drainage ditch, relocating a turnout, etc. It was shown in the
Deschutes project report that the mean cost of operation and maintenance, including supplemental construction for Reclamation Service projects in 1912, was $1.27 per acre. If this could be reduced to not more than 75 cents per acre, the value of the saving capitalized at 6 per cent would represent an equivalent sum of more than $8 in the acre cost of the project. On this basis, if the construction cost for the Ochoco project were the same as that of some other for which the operation and maintenance cost were 50 cents an acre per annum higher, the Ochoco project would in effect be a little over $8 the cheaper of the two.

ALTERNATIVE SMALLER PROJECT (12,300 ACRES).

In the event that the owners of bottom lands should not care to come under the project, there would still be about 12,300 acres of irrigable lands which could be developed.

An estimate has been made on this basis, using the same assumptions as to duty of water and losses as in the previous estimate and adopting the same location.

The total storage required would be 33,000 acre-feet, to secure which it would be necessary to raise the water to elevation 3,118, the top of the dam being at elevation 3,125.

With the smaller storage required for this project, it is probable that serious shortages of water would not occur oftener than an average of once in 25 years.

Estimated cost of smaller project (12,300 acres).

DAM AND RESERVOIR.

Spillway	$56,200
Rock from spillway in dam, 25,800 cubic yards, at $0.25	6,450
Rock from spillway for riprap, 14,200 cubic yards, at $0.50	7,100
Earth from spillway in dam, 16,400 cubic yards, at $0.20	3,280
Earth fill, 426,600 cubic yards, at $0.50	213,300
Cut-off excavation, 12,000 cubic yards, at $0.50	6,000
Outlet tower and conduit	9,000
Temporary diversion	9,000
House for gate keeper	1,500
Rebuilding 5 miles road	5,000
	316,800
Engineering and administration, 25 per cent	79,200
	396,000
Reservoir lands	90,000
Purchasing, legal, land lines, etc	9,000
Total dam and reservoir	495,000

Distributing system.—(12,300 acres alternative.)

The capacity of the main canal at diversion would be only 135 second-feet. It is considered that the canal would be lined for the first one and one-half miles from the dam, and from that point on it would be unlined.

The cost of distribution, from mile 13.83 to the end, would be the same as in the previous estimate, as there is no irrigation of bottom lands from the main canal between those points. The estimated cost of the distributing system is as follows:

Mile 0 to mile 1.5	$21,490
Mile 1.5 to mile 3.3	5,900
Mile 3.3 to mile 5.3	6,200
Mile 5.3 to mile 7	9,550
Mile 7 to mile 8.25	5,780
Mile 8.25 to mile 8.95	5,380
Mile 8.95 to mile 10	3,375
Mile 10 to mile 11.12	1,750
McKay Creek grade crossing	750
Mile 11.12 to mile 13.12	5,780
Mile 13.12 to mile 13.83	2,815
Mile 13.83 to end	31,060
15 bridges, at $40	600
20 inlets, at $20	400
Right of way	5,000
Telephone lines, 16 miles, at $250	4,000
Fence (5-wire), 42 miles, at $125	5,200
	115,030
Engineering and administration, 25 per cent	28,770
Total distribution	143,800
Total reservoir	495,000
Total project	638,800

Estimated cost per acre, 12,300-acre alternative, $51.90.

It is evident, then, that the failure of the bottom lands to come der the project will not affect the cost per acre on the rest. It so justifies the assumption that the equivalent value of the water hts for bottom lands would be 0.6 that for bench lands, or about 0 per acre.

The only other alternative scheme for this project is one for using e waters of Crooked River, which will be discussed under Crooked iver investigations.

CROOKED RIVER INVESTIGATIONS.

SCOPE OF INVESTIGATIONS.

It has been proposed to utilize the flow of Crooked River by proiding storage in a reservoir above Post to irrigate lands in the Haytack Butte and Agency Plains country, and lands now partially irriated from Ochoco Creek above Prineville, together with bottom nds along Crooked River. The possibility of irrigating lands above rineville from the flow of Ochoco Creek is considered elsewhere in his report as the Ochoco project, while the possibility of irrigating he lands of the Haystack Butte and Agency Plains country from the low of Deschutes River has been considered in the report upon the Deschutes project.

It has further been proposed to utilize the flow of Crooked River by providing storage in a reservoir above Post, to regulate the low-water flow of the lower Deschutes for the developing of power. The possibilities of such use have been indicated in the report upon Deschutes River published by the United States Geological Survey in cooperation with the State of Oregon and issued as Water Supply Paper No. 344.

Any complete utilization of the flow of Crooked River should provide for irrigation of bottom lands along Crooked River to the maximum acreage available. About 3,200 acres of land are now irrigated from Crooked River along the bottom. The additional areas suitable for irrigation along Crooked River below the reservoir site at Post are indeterminate. These lands are scattered pockets along the bottom, and would be served by short diversions from the river or possibly by pumping. For the purposes of this report a maximum irrigable area of 5,000 acres has been allowed along the Crooked River bottoms, and in all the possible irrigation and power uses of the flow of Crooked River herein considered reservoir capacity to store sufficient water to irrigate 5,000 acres has been reserved.

The possible methods of utilizing the flow of Crooked River which resulted from the investigations undertaken for this report are as follows:

First. The irrigation with water from Crooked River of that region lying south of Willow Creek to Crooked River, together with all or part of the lands lying around Prineville. This is hereafter referred to as the Crooked River-Haystack Butte alternative. See report o Deschutes project, page 19.

Second. The irrigation with water from Crooked River of land lying around Prineville, hereafter referred to as the Crooked Rive Ochoco alternative.

Third. The regulation of flow of lower Deschutes River for th development of power.

FIELD WORK.

Storing of the waters of Crooked River in a reservoir above Post has long been contemplated for use in irrigating Crooked River bottom lands and those lands lying around and above Prineville, togethe with the lands of the Haystack Butte and Agency Plains country and also for use in developing power by regulating the low-water flow of the lower Deschutes. See Oregon Cooperative report upon Deschute project, North unit, and United States Geological Survey Paper No. 344, "Deschutes River and its Utilization."

A site suitable for reservoir purposes exists at the junction of the north and south forks of Crooked River, about 12 miles east of Post known as the Post Reservoir site.

Topographic surveys.—For Crooked River investigations there was needed the topography of Post Reservoir site and of Crooked River Canyon extending from possible points of diversion to Smiths Rock for canal location, together with topography of irrigable lands about Prineville and that of the Haystack Butte and Agency Plains country. Topography of the Haystack Butte and Agency Plains country was already available from surveys undertaken for the report upon the Deschutes project. (See report Deschutes project, Plates Nos. 26, 27, 28, and 30.) Topography of irrigable lands about Prineville was obtained in investigating the possibility of irrigating these lands from water stored from the flow of Ochoco Creek and referred to elsewhere in this report as the Ochoco project. (See Plate No. 27.) Topography of the Post Reservoir and dam sites was developed from plane table surveys, with horizontal control based upon plane table triangulation and vertical control based upon elevation from U. S. Geological Survey precise level line through the valley. (See Plates Nos. 38 and 49.)

Topography of Crooked River Canyon from Bear Creek to Prineville was developed from plane table surveys with magnetic horizontal control, and vertical control based upon the elevation of the U. S. Geological Survey bench mark at Prineville. (See Plate No. 27.) During the progress of the survey of Crooked River Canyon, it became apparent that the cost of utilizing water from Crooked River to irrigate the Haystack Butte country would be prohibitive, so surveys of the canyon from Prineville to Smiths Rock were not undertaken.

Topography of possible canal diversion sites on Crooked River at Stearns Dam and Hoffmans Dam was developed from plane table rveys and maps were plotted on scale of 1 inch to 200 feet. (See ate No. 39.)

Test borings.—Diamond drill borings were made at the proposed m site for the Post reservoir. The record of borings is as follows:

Hole No. 1. Surface elevation, 3,468.8 feet.

epth in feet.	
0–6.	Bowlders and large gravel.
6–11½.	Solid basalt with a few light seams.
11½–16.	Same as above with fewer seams.
16–27½.	Very solid basalt.

Water loss after reaching rock was all in casing.
Time, September 16, 1914–September 23, 1914.

Hole No. 2. Surface elevation 3,508.9 feet.

0–36.	Mostly bowlders with some earth (possibly slide).
36–46.	Bowlders.
46–52.	Basalt—core short and broken.
52–62½.	Basalt solid—core in good lengths.
62½.	Encountered pocket about 1½ inches across, No water lost at this point.
62½ to 64.	Basalt solid.

No water loss after rock was struck.
Time, September 17, 1914–September 28, 1914.

Hole No. 3. Surface elevation 3,476.9 feet.

0–11.	Bowlders—a little earth mixed in.
11–21.	Solid basalt with light seams all the way down.

Water stands at river level all the way down.
Time, September 24, 1914–September 29, 1914.
Test pit, elevation about 3,519 feet.

A cut was made into the hillside on the north side of the river, about 50 feet above the water surface and about 20 feet upstream from the main line of borings. This shows solid rock outcroppings bearing a rusty appearance on the surface, but fragments from beneath disclosed the same basaltic formation found in the drill holes.

Time, October 6–October 8, 1914.

WATER RESOURCES.

Crooked River.—The headwaters of Crooked River drain from the western slope of the Blue Mountains, and from this region by far the larger portion of its discharge is derived. The remaining and larger portion of the drainage basin consists of low, rolling hills without timber, and from it little or no run-off is derived except in years of exceptional climatic conditions, such that the low country receives a heavy snowfall upon frozen ground, followed by a rapid thaw with heavy rainfall. Under these circumstances extremely large run-off occurs from this portion of the drainage basin.

At Prineville approximately 70 per cent of the run-off occurs during three months of the year, and the river just below Prineville during July, August, and September generally has no appreciable surface flow. Near the mouth of the river a large spring inflow, known a Opal Springs, breaks out from the bottom and sides of the canyon The continuous discharge of these springs is not less than 800 second-feet.

There are numerous diversions of water from Crooked River and its tributaries for irrigating purposes. The total appropriation of water, as recorded at the State water office, is several times the volume of natural flow of the river at Prineville. The total area for which appropriations have been made exceeds 30,000 acres. The greater portion of this acreage can never be served, owing not only to lack of water but also to the lack of necessary reservoir sites to store and utilize the waters of the spring floods.

Deschutes River.—By local custom the Deschutes River drainage basin is divided into three sections—upper Deschutes River Basin, being that above the mouth of Crooked River; Crooked River Basin; and Deschutes River Basin proper, or lower Deschutes River Basin, as it is termed farther north.

A description of upper Deschutes River was given in Deschutes project report, Oregon cooperative work.

An extremely interesting description of both the upper Deschutes River and Crooked River region is found in "Geology and Water Resources of Central Oregon," by Israel C. Russell, 1905. This report by Professor Russell refers more particularly to the geology of the region, but is in his usual entertaining and instructive style. The entire Deschutes River from Benham Falls to its mouth is treated in considerable detail in U. S. Geological Survey Water-Supply Paper No. 344, "Deschutes River, Oregon, and its Utilization."

This latter report is with special reference to power development possibilities on Deschutes River. Writing of the upper Deschutes and Crooked River regions, Russell says:

> After the broad, ancient valley of the Deschutes had been filled to a depth in excess of 700 feet with loose stream-deposited débris, consisting mostly of black volcanic sand and gravel, and this material covered by the widely extended sheet of basalt now forming the surface of the major portion of the Deschutes plain, the rivers displaced from their former courses flowed across the young lava plain and excavated canyons in it, which, in the case of Deschutes and Crooked Rivers, are a mile wide and over 800 feet deep. Next came a flow of molten basaltic rock, which entered the canyons and filled them to a depth of over 550 feet for many miles. Subsequently the same streams, again displaced but still confined to their former but deeply filled canyons, resumed their work of erosion and cut, in solid basalt, the inner canyon described above. In the portion of the canyon examined the task of cutting through this layer is as yet incomplete, and the rivers flow swiftly over solid, compact basalt.

It seems probable that the present lower Deschutes River canyon has been eroded entirely in these later basaltic flows, and particurly in the great lava flow, sometimes referred to as the Columbia iver basalt or lava flow.

The Deschutes canyon, from some distance above the mouth of rooked River to Columbia River, is practically continuous, the first w hundred feet above the river being frequently almost vertical alls, back of which the slopes extend in successive rims or terraces o a height of 1,000 to 1,500 feet.

There are now two railroad lines up the canyon. One of these ines leaves the canyon at Trout Creek and the other at Willow reek, from which points they climb to the table land a few miles ast of the mouth of Crooked River. Here they join and operate over single track, continuing south to the town of Bend. See Plate No. 34.

The flow of Deschutes River is one of the most uniform of the treams of the United States, not only from month to month but lso from year to year. See Deschutes project report, pages 32 to 34. Owing to this great regularity in flow, the lower river has long been regarded as a valuable power stream. To such an extent was this so that at the time the railroads were building up the canyon they were required to so locate their lines as to leave free for future water-power development three important power sites on the lower Deschutes, generally referred to as the Moody, Reclamation, and Sherar Falls sites.

Above the mouth of Trout Creek there are the Mecca, Pelton, and Metolius River sites, unaffected by the railroads. (See U. S. Geological Survey Water Supply Paper 344.)

The following is a list of gaging stations maintained on Deschutes River and tributaries, including Crooked River. The information is taken from Bulletin No. 4, office of State engineer, Water Resources of Oregon, and from unpublished information furnished by Mr. F. F. Henshaw, district engineer for the Water Resources Branch of the United States Geological Survey, with offices in Portland:

List of United States Geological Survey gaging stations in upper Deschutes River drainage basin, Oregon.

No.		Records available for this report.
1	Big Marsh Creek near Crescent	Apr. 1, 1912-Sept. 30, 1914.
2	Crescent Creek near Crescent	Aug. 30, 1912-Oct. 31, 1913. July 13, 1914-Sept. 30, 1914.
3	East Fork of Deschutes River at Morson intake near Lapine	May 26, 1914-Nov. 21, 1914. Mar. 30, 1915-Apr. 30, 1915.
4	East Fork of Deschutes River near Lapine	Sept. 23, 1910-Oct. 31, 1913.[1]
5	East fork of Deschutes River at Allen's Ranch near Lava	Feb. 17, 1905-May 4, 1912. May 27, 1913-Apr. 30, 1915.
6	Deschutes River at West's Ranch near Lava	July 21, 1906-Feb. 20, 1909. Apr. 2, 1914-Sept. 30, 1914.
7	Deschutes River at Benham Falls, near Bend	Mar. 30, 1909-Sept. 22, 1913.
8	Deschutes River at Bend	Dec. 21, 1901-Nov. 21, 1914.
9	Deschutes River at Tumalo (Laidlaw)	Jan. 1, 1909-Oct. 15, 1912. July 14, 1914-Oct. 11, 1914.
10	Deschutes River near Cline Falls	Feb. 15, 1910-Mar. 4, 1911. Feb. 19, 1912-May 31, 1913.

[1] Incomplete.

List of United States Geological Survey gaging stations in upper Deschutes River drainag basin, Oregon—Continued.

No.		Records available for this report.
11	Crescent Creek at outlet of Crescent Lake near Crescent.	Jan. 11, 1911–Apr. 30, 1915.[1]
12	Crescent Creek below Cold Creek near Crescent	Oct. 4, 1912–Dec. 11, 1913.
13	East Fork of Deschutes River near Crescent	Dec., 1904–Mar. 31, 1908. Sept. 25, 1910–Oct. 31, 1913. July 22, 1914–Sept. 30, 1914.
14	Deschutes River at Crane Prairie	Jan. 1, 1914–Apr. 30, 1915.
15	Deschutes River near Lapine	Sept. 22, 1910–Dec. 21, 1910. Feb. 18, 1912–Sept. 12, 1913. Oct. 1, 1914–Apr. 30, 1915.
16	Deschutes River near Lava	Feb. 20, 1905–Apr. 29, 1907. Apr. 23, 1909–Jan. 21, 1911. Oct. 18, 1913–Jan. 9, 1915.
17	Odell Creek near Crescent	Jan. 5, 1912–Sept. 30, 1913. Apr. 12, 1914–Aug. 12, 1914.[1]
18	Tumalo Creek near Tumalo	May 15, 1906–May 17, 1914.[2]
19	Tumalo Creek near Bend	Oct. 6, 1906–Apr. 30, 1915.[3]
	Canals:	
20	Arnold Canal near Bend	Apr. 11, 1914–Apr. 30, 1915.
21	Central Oregon canal near Bend	Mar. 11, 1905–Apr. 30, 1915.
22	Pilot Butte canal near Bend	Mar. 6, 1905–Apr. 30, 1915.
23	North Canal at Bend	June 14, 1913–Apr. 30, 1915.
24	Swalley Canal at Bend	July 5, 1913–Apr. 30, 1915.
25	Wimer Canal near Tumalo	June 16, 1906–Apr. 30, 1915.
26	Columbia Southern Canal near Tumalo	May 15, 1906–Apr. 30, 1915.
27	Tumalo Feed canal near Bend	May 21, 1914–Apr. 30, 1915.
28	Metolius River at Allingham Ranger station, near Sisters.	Sept. 15, 1910–Oct. 31, 1913.
29	Metolius River at Hubbard's Ranch near Grandview	Apr. 24, 1910–Dec. 31, 1913.
30	Metolius River at Riggs Ranch, near Sisters	Oct. 22, 1908–Oct. 21, 1912.
31	Lake Creek near Sisters	Mar. 31, 1911–Oct. 31, 1913.[4]
32	Whitewater Creek, near Grandview	June 2, 1911–Dec. 31, 1913.
33	Crooked River near Post	Nov. 9, 1908–Aug. 31, 1911.
34	Crooked River at Hoffman's ranch near Prineville	Jan. 24, 1913–Sept. 30, 1914.
35	Crooked River at Stearns' Ranch near Prineville	Nov. 3, 1908–Dec. 31, 1912.
36	Crooked River at Prineville	Jan. 11, 1914–Apr. 17, 1914.
37	Ochoco Creek at Prineville	May 14, 1912–July 13, 1912 Dec. 15, 1913–June 20, 1914. Mar. 7, 1915–Apr. 30, 1915.
38	Ochoco Creek at Elliott's ranch near Prineville	Nov. 4, 1908–Apr. 30, 1910. Oct. 26, 1914–Apr. 30, 1915.
39	Squaw Creek near Sisters	July 15, 1906–June 30, 1914.
40	Deschutes River at Lava Island near Bend	Jan. 31, 1915–Apr. 30, 1915.
41	Deschutes River below Bend	Nov. 27, 1914–Apr. 30, 1915.
42	Deschutes River at Mecca	June 7, 1911–Apr. 30, 1915.
43	Deschutes River at Sherar	Feb. 13, 1912–Sept. 30, 1914.
44	Deschutes River near Moro	Oct. 19, 1897–Dec. 31, 1899.
45	Deschutes River at Moody, near Biggs	July 7, 1906–Apr. 30, 1915.
46	Table Land ditch near Prineville	Feb. 24, 1915–Apr. 30, 1915.
47	McKay Creek near Prineville	Feb. 25, 1915–May 31, 1915.
48	Shitike Creek at Warmspring	June 11, 1911–Apr. 30, 1915.
49	Warmspring River near Warmspring	July 29, 1911–Apr. 30, 1915.
50	White River near Tygh Valley	June 18, 1911–Apr. 30, 1915.
51	Tygh Creek at Tygh Valley	June 9, 1911–Oct. 31, 1911. Mar. 9, 1912–Oct. 15, 1912. May 25, 1913–Oct. 31, 1913.

[1] Incomplete.
[2] Records during nonirrigating season kept at Bend Station.
[3] Nonirrigating season only until 1914.
[4] Fragmentary.

CROOKED RIVER STORAGE.

VOLUME OF WATER AVAILABLE FOR STORAGE.

Discharge measurements of Crooked River at Post for three seasons, from 1908 to 1911, are available from records of the United States Geological Survey. The period is too short to give any assurance that the records show extremes in volume of flow or that they indicate the correct mean flow.

Discharge measurements of the river at the Prineville station (see plate No. 33) for the seasons from 1908 to 1914 are available, and by comparison of these records with records at Post for the period of 1908 to 1911 the probable flow of the river at Post for the seasons from 1911 to 1914 has been estimated.

In addition, the records of flow of Crooked River have been compared with those of the John Day at McDonald, and from a study of the relative discharges of these rivers the probable flow of Crooked River has been estimated for the seasons from 1906 to 1908 and 1914–15.

The basis of these estimates is as follows: The average monthly discharge of Crooked River at Prineville for the period from 1908 to 1914 has been compared with the average monthly discharge of John Day River at McDonald for the same period. From percentages thus obtained the probable monthly flow of Crooked River at Prineville for the period from 1906 to 1908 has been estimated as a percentage of the recorded monthly flow of John Day River at McDonald for the same period.

The records of flow of Crooked River at Post have been compared with those of the river at Prineville, month for month. The flow at Post averages 92 per cent of that at Prineville for all months excepting those in which the discharge at Prineville exceeds about 100,000 acre-feet. During these months the flow of the river at Post averaged 80 per cent of that at Prineville. The probable flow of the river at Post for the periods from 1906 to 1908 and from 1911 to 1914 has been estimated at the percentages indicated of the estimated and recorded monthly flow at Prineville.

The relative magnitudes and distributions of flow of Crooked and John Day Rivers for the period from 1907 to 1914 are shown on plate No. 43. The upper diagram indicates the relative distributions of discharges of these streams and tributaries throughout the period, expressed as a rate per second, per square mile of drainage area. The lower diagram indicates the relative magnitudes of total discharges of these streams for the period or portions of period, expressed in acre-feet, per square mile of drainage area.

The total annual flow of Crooked River at Post and Prineville, for the seasonal years October to October, 1906–1915, inclusive, is as follows:

Crooked River at Prineville:	Acre-feet.	Crooked River at Post:	Acre-feet.
1906–7	[1] 417,110	1906–7	[1] 343,460
1907–8	[1] 172,480	1907–8	[1] 159,950
1908–9	189,000	1908–9	175,780
1909–10	375,000	1909–10	268,000
1910–11	204,000	1910–11	172,000
1911–12	308,000	1911–12	[1] 260,820
1912–13	238,310	1912–13	[1] 203,180
1913–14	284,000	1913–14	[1] 237,220
1914–15	[1] 136,000	1914–15	[1] 125,000
Average	258,000	Average	216,000

[1] Estimated.

The maximum departures from the average for the period are, fo Prineville, −47 per cent and +62 per cent; and for Post, −42 pe cent and +59 per cent.

The annual flow of John Day River at McDonald, drainage are 7,800 square miles; John Day River at Dayville, drainage are 1,000 square miles; South Fork of John Day River at Dayvill drainage area 600 square miles; Crooked River at Prineville, drainage area 1,990 square miles; and Crooked River at Post with drainag area of 1,390 square miles, expressed in acre-feet per square mile o drainage area for a period of years is as follows:

	1904–5	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914-
John Day River at McDonald (drainage area 7,800 square miles)	120	183.2	269	129.5	127	192	123	309	226.5	195	[1] 81
John Day River at Dayville (drainage area 1,000 square miles	......	......	......	......	174	209	158	378	240	215	......
South Fork John Day River at Dayville (drainage area 600 square miles)	......	......	......	......	130	183	138	282	162.5	185	......
Crooked River at Prineville (drainage area 1,990 square miles)	......	......	[1] 210	[1] 86.8	96.9	188.5	108.0	155	119.5	143	[1] 68.
Crooked River at Post (1,390 square miles)	......	......	[1] 247.1	[1] 115.1	126.4	192.9	124.4	[1] 187.6	[1] 146.2	[1] 170.4	[1] 90

[1] Estimated.

POST RESERVOIR.

Crooked River canyon above Prineville Valley is frequently broke by narrow basins, which here and there broaden out into valleys similar to that of Prineville. None of the basins between Prineville Valley and North Fork are of a size to provide sufficient capacity for reservoir sites.

Immediately below the mouth of North Fork the canyon is ver narrow and at a little over a half mile below the fork provides a ideal dam site. (See Plate No. 38.) For a distance of about 8 miles above North Fork the valley spreads out to a width of from 1 to miles.

Dam—Estimates of cost for different types.—Owing to lack of transportation facilities, the cost of developing storage on Crooked River at the present time is largely a question of the cost of constructing a dam. The site for the dam (see Plate No. 38) lies in a narrow canyon with rock walls, such that a single arch masonry dam may be advantageously employed. Storage flow from the reservoir, through a tunnel beneath the dam, will be controlled from a gate tower. Two sets of sluice gates placed in series will provide means of controlling the volume of discharge.

When the maximum depth of water in the reservoir, acting upon the sluice gates, exceeds 50 feet, the effective depth over each gate will be reduced to one-half the maximum by means of an automatic bypass, controlled by float valves.

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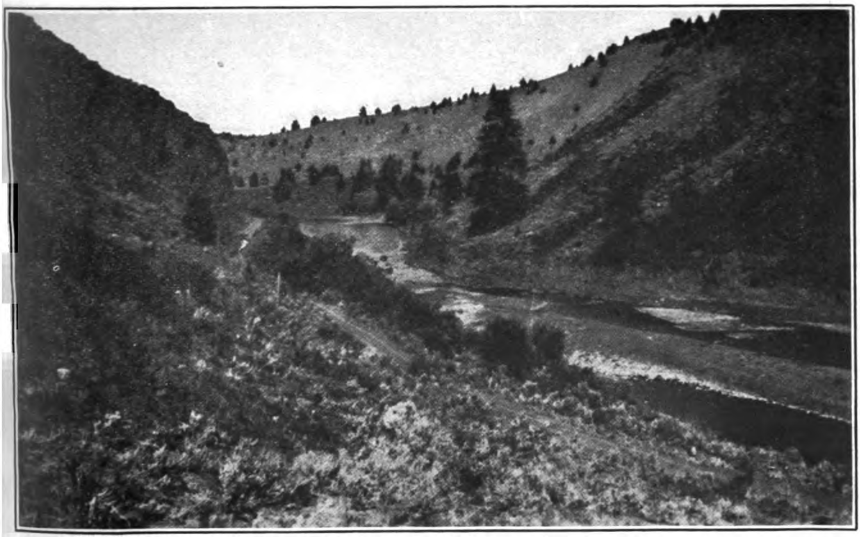

POST RESERVOIR DAM SITE, LOOKING DOWNSTREAM.

The estimated cost of a single arch structure (see Plate No. 40) to se the water 131.2 feet and provide a net reservoir capacity of ,000 acre feet, is as follows:

Single arch type of dam—Crest elevation 3,600.

cavation:	
Loose rock, 16,000 cubic yards, at $1	$16,000
Solid rock, 4,000 cubic yards, at $1.50	6,000
sonry: Concrete, 48,000 cubic yards, at $11.25	540,000
fferdam and diversion works	2,000
Outlet, tower, and gates	16,000
Keeper's house and buildings	5,500
	585,500
gineering, administration, and contingencies, 25 per cent	146,500
Total	732,000

A multiple arch type of dam may be utilized at this site and at a ss cost of construction than that for the single arch type. The timated cost of a multiple arch type of dam, to raise the water 31.2 feet and provide a net reservoir capacity of 260,000 acre-feet, as follows:

Multiple arch type of dam—Crest elevation, 3,600.

xcavation:	
Loose rock, 5,000 cubic yards, at $1	$5,000
Solid rock, 2,500 cubic yards, at $1.50	3,750
asonry: Reinforced concrete, 25,500 cubic yards, at $19	484,500
offerdam and diversion works	2,000
utlet, tower, and gates	16,000
eeper's house and buildings	5,500
	516,750
ngineering, administration, and contingencies, 25 per cent	129,250
Total	646,000

Lands.—There are a number of well-developed hay and stock anches in the Post Reservoir basin. A small amount of grain, mostly ats, is also grown. The relative area of improved lands, however, s small. Part of these lands only are served by ditches and have water rights.

By far the larger portion of the basin is entirely unimproved except by fencing. Large areas of the bottom lands now show the effects of alkali, and any considerable amount of irrigation in the basin, if water were available, would necessitate drainage. These unimproved bottom lands can not therefore be considered so valuable as improved bottom lands along the river.

Outside of the bottoms, the lands coming within the reservoir site are hill lands, largely rim rock and talus, and often of no value whatever. The area of this class of land is larger than the total of all classes of bottom lands.

In estimating the area to be acquired for reservoir site the maximum elevation below which all lands must be acquired has been placed at

10 feet above the spillway crest. Each entire 40-acre tract which is cut by this contour is included in the estimated area to be acquired.

There is a small amount of unpatented land within the reservoir site to which no value has been attached in the estimates, on the assumption that it can be acquired from the United States without cost under the land laws governing reservoir sites.

Following is the estimated cost of lands to be acquired for reservoir, with spillway crest at elevation 3,600 feet:

1,100 acres improved bottom lands, at $60	$66,000
400 acres improved bottom lands, at $35	14,000
2,400 acres unimproved bottom lands, at $20	48,000
3,780 acres unimproved hill land, at $5	18,900
1,720 acres unpatented land, at $0	0
9,400 acres	146,900
Say	150,000
Legal services, land lines, administration, etc	15,000
Total	165,000

The lands necessary to be acquired for reservoir, with spillway at elevation 3,565 feet, are as follows:

1,000 acres improved bottom lands, at $60	$60,000
400 acres improved bottom lands, at $35	14,000
2,250 acres unimproved bottom lands, at $20	45,000
2,300 acres unimproved hill land, at $5	11,500
1,250 acres unpatented land, at $0	0
7,200 acres	130,500
Say	130,000
Legal services, land lines, administration, etc	15,000
Total	145,000

Reservoir costs for varying capacities.—For a reservoir with a a capacity of 260,000 acre feet, the purchase of 9,400 acres of land will be necessary at the estimated cost of $165,000. The resulting estimated reservoir cost for a capacity of 260,000 acre feet with a single-arch type of dam is $897,000, at $3.44 per acre-foot of capacity, and for a multiple-arch type $812,000, at $3.12 per acre-foot capacity.

From a study of costs of structures of various heights and their relative reservoir capacities and areas, the following table of reservoir costs per unit of capacity has been prepared:

Reservoir (capacity acre-foot).	Cost per acre-foot of capacity.		Reservoir (capacity acre-foot).	Cost per acre-foot of capacity.	
	Single-arch type.	Multiple-arch. type.		Single-arch type.	Multiple-arch. type.
300,000	$3.50	$3.19	150,000	$3.85	$3.60
270,000	3.43	3.10	120,000	4.08	3.90
240,000	3.48	3.17	90,000	4.58	4.37
210,000	3.63	3.33	60,000	5.90	5.50
180,000	3.74	3.46	35,000	8.50	8.00

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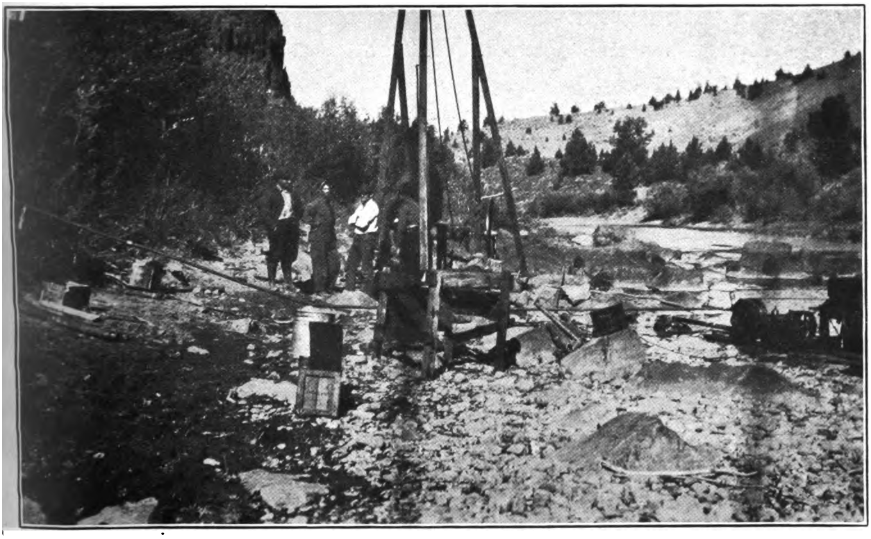

POST RESERVOIR DAM SITE, LOOKING DOWNSTREAM; SHOWING DIAMOND DRILL.

Type adopted.—A dam at Post reservoir site will be subject to the tion of ice pressure. The effect of ice, freezing in the groin of a ultiple-arch dam, is uncertain. As there is no known existing ample of a high multiple-arch type of dam for reservoir purposes, cated in a climate where heavy ice is formed, all estimates of reservoir d storage costs for the several developments considered in this port will be based upon the cost of single-arch type of dam.

Future development of transportation facilities in Crooked River asin will materially lessen the cost of constructing the dam. Howver, improvements in the valley due to resulting colonization will end to counterbalance this decreased cost of construction by increasg the value of lands within the reservoir site.

Evaporation.—Losses of water from Post reservoir by evaporation ave been assumed to be equivalent to a depth over reservoir surace of 4 feet per annum, distributed as follows:

anuary	0.00	August	0.70
ebruary	.10	September	.50
arch	.30	October	.20
pril	.50	November	.10
ay	.50	December	.00
une	.50		
uly	.60	Annual	4.00

For discussion of evaporation see Deschutes project report, page 65.

Seepage.—Seepage losses of water from the reservoir at Post will be assumed at 15 per cent of reservoir capacity. Seepage return to the river will be assumed to be above the point of canal diversion and to be equivalent to these losses. Its distribution throughout the year will be considered as constant. For discussion of this subject see Deschutes project report.

IRRIGATION.

DUTY OF WATER.

The monthly diversion requirements of water per acre, assumed for lands of the north unit of the Deschutes project, expressed in acre-feet (see report Deschutes project, p. 87), are as follows:

May	0.405	September	0.27
June	.675	Nonirrigating season	.50
July	.81		
August	.54	Annual	3.20

The monthly diversion requirements of water per acre, assumed for lands of the Ochoco project, considered elsewhere in this report, expressed in acre-feet, are as follows:

May	0.32	September	0.15
June	.58		
July	.67	Annual	2.17
August	.45		

The length of diversion canals required to serve the above lands in the developments here considered is somewhat greater than that required for the projects for which the above assumptions were made. However, the additional water required to cover canal seepage losses will for the purposes of this report be negligible, and diversion duties of water as above will be assumed for lands of the Crooked River-Haystack Butte alternative and the Crooked River-Ochoco alternative.

For bottom lands along Crooked River a diversion duty of water equal to that assumed for the Ochoco project will be used.

CROOKED RIVER-HAYSTACK BUTTE ALTERNATIVE.

A project to irrigate all of the lands lying south of Willow Creek and west of Haystack Butte to Crooked River on the south and Deschutes River on the west may be developed either by building a low-line canal to reach these lands at the least cost and incidentally serving such lands around Prineville as lie below this canal; or by a high-line canal serving the Haystack Butte country, together with the major portion of the lands around Prineville. Approximately 46,000 acres of land in the Haystack Butte country will be served by either canal, while the low line will serve about 9,000 acres and the high line about 15,000 acres of land around Prineville. The total areas served by the low-line canal will be 55,000 acres, and by the high line, 61,000 acres.

Reservoir capacity is provided for storage water sufficient to irrigate both the lands served by the main canal for either alternative of this project, and 5,000 acres of bottom lands along Crooked River. These lands will not be served from the main canal.

Low-line canal development.—The total assumed diversion requirement for the low-line development, expressed in acre-feet, is as follows:

	Haystack Butte country (46,000 acres).	About Prineville (9,000 acres).	Crooked River bottom lands (5,000 acres).
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
May	18,700	2,880	1,600
June	31,000	5,210	2,900
July	37,300	6,030	3,350
August	24,800	4,050	2,250
September	12,400	1,350	750
Nonirrigating season	23,000		
Annual	147,200	19,520	10,850

The assumed annual diversion requirement for the low-line canal development of the Crooked River-Haystack Butte alternative is 177,570 acre-feet. Sufficient storage to supply this assumed diversion requirement, on the basis of a 25 per cent deficiency during one

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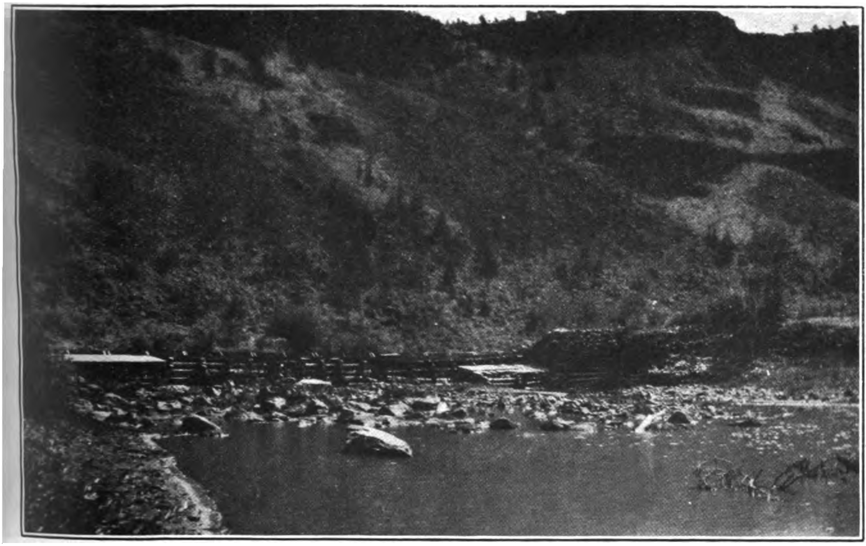


STEARNS DIVERSION DAM ON CROOKED RIVER.

son in ten, will be provided in a reservoir at Post. A reservoir th a capacity of 150,000 acre-feet at Post, during the period from 6 to 1915, would have provided storage sufficient to supply the ire assumed diversion requirement during the seasons of 1907, 8, 1910, 1912, 1913, and 1914. A shortage of 2 per cent of the uirements would have occurred during seasons of 1909 and 1911, d a probable shortage of 20 per cent during the season of 1915.

The possible regulation of storage in a reservoir of 150,000 acre-ot capacity at Post, to supply the assumed diversion requirement r this low-line canal development, is shown by the following table:

timated manipulation of storage at Post for irrigation Crooked River—Haystack project, low line development.

A. Date.	B. Reservoir-inflow Crooked River at Post.	C. Flow of Crooked River at Prineville.	D. Diversion requirements.	E. Evaporation and seepage losses from reservoir.	F. Water in reservoir at beginning of month.	G. Overflow and shortage.
1906.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
tober	2,400	2,590	3,300	20	730	....
vember	7,450	8,060	3,300	....	....	....
ecember	11,250	12,100	3,300	....	4,760	....
1907.						
nuary	12,900	13,950	3,300	....	13,560	....
bruary	92,000	115,000	3,300	2,130	24,2 0	(1)
arch	92,000	115,090	3,300	3,070	114,080	53,070
pril	86,000	107,500	3,300	4,250	150,000	81,750
ay	30,000	32,600	23,180	2,250	150,000	7,170
ne	5,050	5,440	39,110	2,250	150,000	....
y	1,470	2,220	46,680	2,340	114,0 0	....
ugust	1,470	1,6 0	31,100	2,030	67,280	....
eptember	1,490	1,660	14,500	1,450	35,760	....
ctober	2,640	2,890	3,300	240	21,470	....
ovember	6,350	6,910	3,300	120	20,820	....
ecember	9,050	9,820	3,300	....	24,310	....
1908.						
anuary	8,000	8,640	3,300	....	30,830	....
ebruary	9,750	10,600	3,300	190	36,170	....
arch	48,300	52,300	3,300	2,630	43,250	....
pril	51,670	55,670	3,300	3,600	88,850	....
ay	15,700	17,000	23,180	2,100	136,920	....
une	4,820	5,230	39,110	2,070	128,640	....
y	1,720	1,8 0	46,680	2,100	92,710	....
ugust	860	905	31,100	1,540	46,740	....
eptember	1,190	1,275	14,500	500	15,010	....
ctober	2,910	2,460	3,300	20	1,260	....
ovember	5,010	3,870	3,300	10	910	....
ecember	4,930	4,600	3,300	....	2,660	....
1909.						
anuary	11,600	12,600	3,300	....	4,290	....
February	21,900	23,400	3,300	2,100	13,590	....
March	43,900	47,000	3,300	2,570	33,390	....
April	56,500	68,000	3,300	3,500	73,820	....
May	19,800	17,200	23,180	2,050	127,120	....
June	4,400	4,090	39,110	2,000	121,190	....
July	2,450	2,200	46,680	1,920	84,480	....
August	1,160	1,600	31,100	1,400	38,830	(2)
September	2,010	2,120	14,500	350	7,430	5,300
October	3,440	3,100	3,300	....	....	....
November	25,600	31,500	3,300	2,010	140	....
ecember	13,200	14,300	3,300	....	23,730	....
1910.						
anuary	21,600	22,700	3,300	....	34,730	....
ebruary	38,300	51,700	3,300	2,220	54,130	(1)
arch	117,000	200,600	3,300	2,990	90,2 0	54,220
pril	35,500	37,400	3,300	3,150	150,000	81,250
ay	9,350	11,500	23,180	2,250	150,000	....
une	916	857	39,110	2,100	136,070	....
uly	1,060	548	46,680	2,100	95,780	....

[1] Overflow.

[2] Shortage.

Estimated manipulation of storage at Post for irrigation Crooked River—Haystack pr ect, low line development.—Continued.

A. Date.	B. Reservoir-inflow Crooked River at Post.	C. Flow of Crooked River at Prineville.	D. Diversion requirements.	E. Evaporation and seepage losses from reservoir.	F. Water in reservoir at beginning of month.	G. Overflo and shortag
1910.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-fee*
August	633	347	31,100	1,540	48,060	...
September	1,660	1,110	14,500	500	16,050	...
October	2,840	2,820	3,300	40	2,710	...
November	6,070	6,310	3,300	20	2,210	...
December	16,800	18,300	3,300	2,000	5,200	...
1911.						
January	8,980	9,780	3,300	...	20,000	...
February	9,660	10,500	3,300	150	26,480	...
March	62,700	80,600	3,300	2,540	33,530	...
April	45,800	52,600	3,300	3,750	93,690	...
May	14,800	18,200	23,180	2,100	135,640	...
June	2,550	2,650	39,110	2,050	128,660	...
July	806	1,080	46,680	2,100	90,150	...
August	762	572	31,100	1,750	42,450	[1]
September	990	1,080	14,500	600	10,360	3,
October	2,870	3,120	3,300	...	...	
November	3,660	3,970	3,300	...	...	...
December	4,550	4,960	3,300	...	670	...
1912.						
January	19,800	21,800	3,300	2,000	2,330	...
February	36,100	39,200	3,300	2,120	20,130	...
March	20,400	22,200	3,300	1,250	54,110	...
April	76,200	95,200	3,300	3,500	71,760	[2]
May	73,300	91,600	23,180	2,150	144,460	60,730
June	16,400	17,800	39,110	2,250	150,000	...
July	3,800	4,120	46,680	2,460	126,440	...
August	1,870	2,040	31,100	2,240	81,420	...
September	1,870	2,040	14,500	1,100	50,120	...
October	2,780	3,020	3,300	380	36,560	...
November	4,700	5,090	3,300	190	35,900	...
December	6,950	7,620	3,300	...	37,500	...
1913.						
January	6,060	6,580	3,300	...	41,820	...
February	10,000	11,100	3,300	220	45,100	...
March	35,400	38,900	3,300	2,750	52,680	[2]
April	96,500	121,000	3,300	3,600	85,330	28,230
May	31,620	34,800	23,180	2,250	150,000	9,370
June	3,610	3,920	39,110	2,250	150,000	...
July	2,400	2,580	46,680	2,340	112,560	...
August	2,030	2,190	31,100	1,960	66,120	...
September	1,130	1,220	14,500	950	35,250	...
October	3,440	3,730	3,300	240	21,020	...
November	5,530	6,010	3,300	120	21,210	...
December	4,570	4,970	3,300	...	23,800	...
1914.						
January	12,900	14,000	3,300	2,000	25,470	...
February	22,300	24,300	3,300	190	36,370	...
March	85,600	107,000	3,300	750	56,480	[2]
April	74,620	93,400	3,300	2,150	139,330	59,800
May	17,900	19,500	23,180	2,250	150,000	...
June	6,730	7,320	39,110	2,200	144,070	...
July	2,000	2,180	46,680	2,280	110,080	...
August	400	441	31,100	1,960	63,300	...
September	1,230	1,340	14,500	900	30,680	...
October	3,080	2,340	3,300	200	16,620	...
November	5,950	6,460	3,300	100	17,040	...
December	6,150	6,680	3,300	...	20,100	...
1915.						
January	6,150	6,680	3,330	...	23,480	...
February	8,320	9,050	3,330	160	26,860	...
March	30,000	32,600	3,330	540	32,450	...
April	40,000	44,300	3,330	1,350	59,910	...
May	20,000	22,200	23,180	1,700	96,560	...
June	3,000	3,300	39,110	1,700	93,880	...
July	800	880	46,680	1,560	56,370	[2]
August	800	880	31,100	560	10,010	20,770
September	1,000	1,100	14,500	...	...	13,400

[1] Shortage.

[2] Overflow.

In columns B and C are shown the magnitudes of the estimated d recorded monthly runoffs of Crooked River at Post and Prinele, respectively. In column D is shown the assumed diversion uirement for the low-line development of this Crooked Riverystack Butte alternative. In column E is shown the magnitude resulting losses of water from the reservoir by seepage and aporation.

In column F is shown the volume of water stored in the reservoir the beginning of the month, while in column G is shown the volne of excess water wasted by overflow from the reservoir, together th the volumes of water by which the storage fails to meet assumed version requirements. The water shortages appear in the table to cur as a total deficiency at the end of the season, and are so shown r purposes of illustration. In actual practice the water available r irrigation during any season can be closely estimated at the benning of that season, and any shortage will be distributed by the ers throughout the irrigating period.

The main canal for low-line development of this project would vert from the river at a point in section 33, township 16 south, range 5 east, by means of a low diversion dam and running down Crooked iver Canyon would cross Ochoco Creek south of Barnes Butte by eans of a pipe crossing. Swinging around the west side of Barnes utte through the irrigable lands above Prineville it would reenter rooked River Canyon and connect with the canal line as projected for eschutes north unit project at Smiths Rock. From this point the anal will follow the location as determined for the Deschutes project. See Deschutes report, page 134.) The length of main canal for this w-line development will be 75 miles. The canal would be concrete ned throughout. See Plate No. 41.

High-line development.—The total assumed diversion requirement or the high-line development, expressed in acre feet, is as follows:

	Haystack country (46,000 acres).	About Prineville (15,000 acres).	Crooked River bottom lands (5,000 acres).
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
ay	18,700	4,800	1,600
une	31,000	8,700	2,900
uly	37,300	10,100	3,350
ugust	24,800	6,750	2,250
eptember	12,400	2,250	750
onirrigating season	23,000	....	....
Annual	147,200	32,600	10,850

The assumed annual diversion requirement for high-line canal development of the Crooked River-Haystack Butte alternative is 190,650 acre-feet. Sufficient storage to supply the assumed diversion requirement, on the basis of a 25 per cent deficiency during one season in ten, will be provided in a reservoir at Post. A reservoir with a capacity of 170,000 acre-feet at Post during the period from 1906 to 1915 would have provided storage sufficient to supply the entire assumed diversion requirement during the seasons of 1907, 1908, 1910, 1912, 1913, and 1914.

A shortage of 4 per cent of the requirement would have occurred during the season of 1911, a shortage of 8 per cent during 1909, and a probable shortage of 25 per cent during the season of 1915.

The main canal for the high-line development of this project would divert from the river in Sec. 10, T. 17 S., R. 16 E., by means of a low diversion dam, and running down the Crooked River Canyon would cross Ochoco Creek by means of a pipe crossing; thence, passing around and above the irrigable lands back of Prineville it would reenter Crooked River Canyon and follow on a higher grade the same general location as for the low-line development to Smiths Rock. From there on the location of the canal is identical with that of the low-line development. The main canal for this high-line development is 83.5 miles long and is concrete-lined throughout. See Plate No. 41.

Estimates of cost.—During the progress of surveys for this Crooked River-Haystack Butte alternative it became apparent that the cost of utilizing water from Crooked River to irrigate the Haystack Butte country would be prohibitive, so surveys of the canyon from Prineville to Smiths Rock were not undertaken. For this reason estimates of this portion of the diversion canal are approximate only. Estimates of the cost of diversion canals, based upon surveyed line, were made from a study of the cost of typical sections for the average of conditions encountered, taken from carefully estimated canal costs for the units of the Deschutes report. Costs given include a charge for engineering administration and contingencies, equivalent to 20 per cent of the estimate.

Estimated cost of low-line development.

Post Reservoir:	
150,000 acre-feet, at $3.85	$577,500
Diversion dam	25,000
Canals:	
Mile 0 to mile 18.5, 18.5 miles, at $50,000	925,000
Mile 18.5 to mile 19, Ochoco Creek pipe crossing	75,000
Mile 19 to mile 35, 16 miles, at $38,000	608,000
Mile 35 to mile 47, 12 miles, at $48,000	576,000
Mile 47 to mile 75, 28 miles, at $34,000	952,000
Distributing system, 46,000 acres, at $10.50	483,000
Distributing system, 9,000 acres, at $4.60	41,400
55,000 acres, at $77.52	4,262,900

Estimated cost of high-line development

st Reservoir:	
170,000 acre-feet, at $3.78	$642,600
Diversion dam	25,000
nals:	
Mile 0 to mile 25, 25 miles, at $60,000	1,500,000
Mile 25 to mile 25.5, Ochoco Creek crossing	200,000
Mile 25.5 to mile 43.5, 18 miles, at $40,000	720,000
Mile 43.5 to mile 55.5, 12 miles, at $40,000	480,000
Mile 55.5 to mile 83.5, 28 miles, at $34,000	952,000
Distributing system, 46,000 acres, at $10.50	483,000
Distributing system, 15,000 acres, at $4.60	69,000
61,000 acres, at $83.14 per acre	5,071,600

CROOKED RIVER—OCHOCO ALTERNATIVE.

It has been proposed to irrigate lands around Prineville, heretofore ferred to under Crooked River-Ochoco alternative, with water to be aken from Crooked River and supplied to the land either by gravity r by pumping. Approximately 15,500 acres of land around Prineville ill be served, and reservoir capacity must be provided at Post to tore water sufficient to irrigate these lands, together with 5,000 acres n Crooked River bottom.

The assumed diversion requirement for the Crooked River-Ochoco lternative is as follows:

About Prineville (15,500 acres):	Acre-feet.
May	4,960
June	8,990
July	10,385
August	6,975
September	2,325
Annual	33,635

Crooked River bottom lands (5,000 acres):	Acre-feet.
May	1,600
June	2,900
July	3,350
August	2,250
September	750
Annual	10,850

The assumed annual diversion requirement for the Crooked River, Ochoco alternative is 44,485 acre-feet. Sufficient storage to supply the assumed diversion requirement, with a full supply for the assumed 10 per cent dry year, will be provided at Post in a reservoir of 35,000 acre-feet capacity.

Gravity development.—The diversion canal for a gravity supply will take out from the river in sec. 10, T. 17 S., R. 16 E., by means of a low diversion dam. Running down Crooked River Canyon it would cross Ochoco Creek south of Barnes Butte as a pipe crossing, and continue thence to the distributing system.

The diversion dam is designed to raise the water about 8 feet. The main diversion canal will be concrete lined for a portion of its length, while the remainder will be in earth. The type of construction for the distributing system will be of the same character as that design for the Ochoco project. (See Plates Nos. 31 and 36.)

Pumping development.—Water will be diverted from the river a Stearns dam in sec. 1, T. 16 S., R., 15 E., by means of a low diversio weir, and conducted by gravity to a pumping station on the sout side of Barnes Butte. The system of distribution heads in thre main distributing canals. The lower canal will take out from th diversion canal by gravity and serve 3,500 acres of land, lying belo elevation 2,910. The intermediate distributing canal will serv 7,800 acres, lying between elevation 2,910 and 2,960, by means of a pump lift of 51 feet. The high line distributing canal will serve 4,20 acres, lying between elevation 2,950 and 3,030, by means of a pump lift of 126 feet.

For purposes of this report, it is assumed that 2,000 horsepower, the power necessary to operate the pumping plant, will be developed on Deschutes River at Dillon Falls and transmitted to Prineville. (See Deschutes report, page 126.)

The extent of the present commercial power market, served by local power companies throughout this region, is so limited that it is probable that these companies could not use the power output of this plant during the nonirrigating season; estimates of cost are made upon the basis of charging to this development the entire cost of the power installation necessary to operate the pumping plant.

The diversion dam is designed to raise the water about 8 feet. An earth canal will conduct the water to Ochoco Creek, which will be crossed by a metal flume to the pumping station. The pumping plant will consist of two direct connected motor centrifugal pump units, for both lifts. For the low lift, two 410 horsepower units and for the high lift two 550 horsepower units, together with necessary transformers and switchboard apparatus, will be required.

Steel force mains will conduct the water from pumps to distributing canals. The type of construction for distributing systems will be of the same character as that designed for the Ochoco project. (See Pls. Nos. 31 and 36.)

Estimates of cost.

Gravity development:	
Storage, Post Reservoir, 35,000 acre-feet, at $8.50	$297,500.00
Diversion dam	25,000.00
Canal—	
Mile 0 to mile 15, 15 miles concrete-lined canal, at $25,000	375,000.00
Mile 15 to mile 25, 10 miles earth canal, at $13,000	130,000.00
Mile 25 to mile 25.5 Ochoco pipe crossing	70,000.00
Distributing system, 15,500 acres, at $11	170,500.00
Total (15,500 acres, at $68.90)	1,068,000.00

umping development:	
Storage, Post Reservoir, 35,000 acre-feet, at $8.50	$297,500.00
Diversion dam at Stearns	25,000.00
Diversion canal, Stearns to Ochoco Creek, 9 miles, at $12,000	108,000.00
Metal flume, Ochoco Creek crossing, 2,500 feet, at $6	15,000.00
Pumping station and equipment—	
Low pumping lift—	
300 feet 30-inch steel pipe, at $6	1,800.00
2 units 350 horsepower motors and 24-inch centrifugal pumps	19,000.00
High pumping lift—	
600 feet 24-inch steel pipe, at $5	3,000.00
2 units 450 horsepower motors and 20-inch centrifugal pumps	20,400.00
Step-down transformers, 1,450 kilowatts, at $4	5,800.00
Switchboard	2,000.00
Pump house and pit	10,000.00
Distributing system, 15,500 acres, at $11	170,500.00
Power plant, Dillon Falls, 2,000 horsepower, at $70	140,000.00
Transmission line to Prineville, 38 miles, at $2,000	76,000.00
Construction cost (15,500 acres, $57.68)	894,000.00
otal constructing cost per acre	57.68
apitalized operating cost and depreciation of power and pumping plant, $1.92 per acre, at 6 per cent per acre	32.00
Total cost per acre	89.68

The estimated cost of operating power and pumping plants is as ollows:

nnual operating cost of power plant at Dillon Falls and transmission line to Prineville:	
Labor	$3,500
Supplies, repairs, and contingencies	5,000
Overhead charges	1,000
Equipment depreciation, 10 years on $63,000 at 3 per cent	5,500
Equipment depreciation, 20 years on $100,000 at 3 per cent	3,700
15,500 acres, at $1.21	$18,700
Annual operating cost of pumping plant at Prineville:	
Labor	2,500
Supplies, repairs, and contingencies	2,300
Equipment depreciation, 10 years on $67,000 at 3 per cent	5,800
Overhead charges	400
15,500 acres at 71 cents	11,000

Possible preliminary development of pumping supply.—It will be possible to develop this Crooked River-Ochoco pumping project in two stages. Preliminary development would consist in providing the entire storage for the project, and constructing the diversion dam and canal, with flume across Ochoco Creek to the pumping plant.

A preliminary development of the pumping plant would be mad with one unit each of high and low lifts installed, and the distributin system would be constructed to include at this time, distributin canals and sufficient laterals to supply lands which require immediat delivery of water. If possible, off peak load power would be purchase from commercial power companies in the field, and any necessar transmission line to transmit this power to Prineville would be i stalled by the irrigation district, providing that this line would b economical for a final transmission of power from Dillon Falls.

The final development would consist of installing the two addi tional pumping units, completing the distributing system, an developing the necessary power at Dillon Falls.

Estimates of the cost of developing the project in the foregoin manner, are as follows:

Post reservoir		$297,5
Diversion dam at Stearns		25.0
Diversion canal, 9 miles, at $12,000		108.0
Metal flume, Ochoco Creek crossing, 2,500 feet at $6		15,0
Pumping station and equipment:		
One low-lift pumping unit		9,50
One high-lift pumping unit		10,20
Steel pipe force mains		2,40
Step-down transformers, 725 kilowatts		2.90
Switchboard		1.00
Pump house and pit		10.00
Distributing system, 10,000 acres, at $11		110.00
Preliminary power development at Dillon Falls:		
1,000 horsepower capacity	$100,000	
Transmission line	60,000	
		160,000
Total cost		751,500

If power companies will sell power delivered at, say, Redmond, a transmission line from Redmond to Prineville would alone be required. The location of this line would be such that it would form a link in the transmission line for final power development and transmission from Dillon Falls.

Estimated cost of construction of such a preliminary development is as follows:

Reservoir, diversion works, canals, pumping plant, and distributing syatem.	$591,500
16 miles transmission line	24,000
Total	615,500

POWER.

Storage of the flood water of a stream can not be utilized to develop power upon that stream by increasing its low-water flow, unless fall be previously developed upon it; this previous development of fall presupposes the development of power from the natural flow.

A given fall having been developed, the economic advantage of the ilization of storage is a question of the cost of additional power, iich may be developed by utilization of that storage, to increase e usable flow of the river over this fall, as compared with the cost additional power obtained by developing another fall.

The cost of developing water power by utilizing the natural flow a stream consists of (1) the cost of developing fall and (2) the cost constructing forebays, power house, and machinery to transform d transmit the power in useful form to the place of consumption. ie cost of developing water power by storing flood waters for use increasing the low-water flow of the stream over a previously de- loped fall consists of (3) the cost of providing storage and (4) the st of constructing additional forebays, power house, and machinery transform, etc. It is evident, providing that the costs of con- ructing forebays, etc., in each case are equal, that the minimum cost increasing the power upon a stream is a question of the relative st of developing additional fall or providing storage to supplement e low-water flow of the stream. In one case the total developed ll upon the stream is increased, in the other case the usuable flow f the stream is increased.

PROBABLE FUTURE FLOW—LOWER DESCHUTES RIVER.

Discharge measurements upon lower Deschutes River near Moody, about 3 miles from the Columbia, and at Mecca, about 15 miles below he junction of Crooked River with the Deschutes, are available from ecords of the United States Geological Survey. The flow of Deschutes River during the period of record has been progressively reduced y the diversion of waters from the upper Deschutes for irrigating use. The future development of the upper Deschutes, as pre- sented in the report upon the Deschutes project, contemplates the complete utilization for irrigating purposes of the flow of the Deschutes above Benham Falls, together with the waters of Tumalo Creek.

From the records of flow of the Deschutes at Mecca and Moody and the records of diversions of water into the Central Oregon Canal, Pilot Butte Canal, North Canal, Arnold Ditch, Swalley Ditch, Columbia Southern Canal, Wimer Ditch, and Tumalo Diversion Canal, the probable natural flow of the Deschutes at Mecca and at Moody for the period of record has been estimated. (For Moody, see column C, table, p. 88.)

To arrive at a probable future modified flow of the lower Deschutes, on the assumption that the entire flow of the upper Deschutes above Benham Falls and that of Tumalo Creek are appropriated to irrigation uses, it would seem at first sight that, including the discharge of Crooked River, the entire flow of these upper streams mentioned should be deducted from the estimated probable natur flow of the lower Deschutes.

A large percentage of the water actually diverted from the riv for irrigating purposes is, however, lost to actual plant consumptio by seepage in canals and subdrainage from the cultivated area The greater portion of these losses will return to the river flow abov Mecca through ground-water storage.

The total annual appropriation of waters from the upper Des chutes for a complete utilization of the flow for irrigating use ha been estimated in the report upon the Deschutes project to b 1,210,000 acre feet (p. 33, Deschutes project report), and the possibl appropriation of water from Tumalo Creek will be assumed, for th purpose of this report, to be 76,000 acre-feet.

A continuous flow to the river of 35 per cent of the assumed appro priations of 1,286,000 acre-feet for irrigating uses, equivalent t 620 second-feet, will be assumed to take place. (U. S. Geologic Survey, Water Supply Paper No. 344, p. 114.)

The probable flow of the lower Deschutes at Moody and Mecc after deducting the estimated flow of Crooked River, has been esti mated for the period of record as it would have occurred with th flow of the upper Deschutes and Tumalo Creek appropriated fo irrigating use. (For Moody see column D, table, p. 88, and Hydro graph plate No. 44.)

The annual discharge of the Deschutes as recorded at Moody, together with the percentages of variation of annual discharge from the mean annual discharge for the period, is as follows:

Date.	Annual discharge.	Variation from average.	Date.	Annual discharge.	Variation from average.
	Acre-feet.	*Per cent.*		*Acre-feet.*	*Per cent.*
1906-7	5,700,000	+14.7	1911-12	5,100,000	+ 2
1907-8	4,940,000	− 0.6	1912-13	4,840,000	− 2
1908-9	4,670,000	− 6.0	1913-14	4,410,000	−11.
1909-10	5,690,000	+14.5			
1910-11	4,420,000	−11.0	Mean for period	4,971,000	

The annual discharges of the Deschutes, as recorded at Mecca for the period of record, are as follows:

	Acre feet.
1911-12	3,765,000
1912-13	3,690,000
1913-14	3,650,000

From an inspection of the hydrograph of the Deschutes at Moody (plate No. 44) it will be noted that years of minimum flow occur in couplets. For the period of records the years 1907 and 1908 and years 1910 and 1911 are years of minimum run-off for the Deschutes at Moody. The year 1914 was a year of low run-off, and from present indications the year 1915 will be a year of lower run-off than any of record.

ENERAL CONDITIONS AFFECTING RIVER AND POWER REGULATION.

Fluctuation of stream flow.—The volume of flow of a stream varies om day to day and from one season to another. In streams of latively small drainage area hourly fluctuations of flow will occur uring certain seasons of the year.

Fluctuation of power demand.—The magnitude of the average noral rate of power demand from a power market large enough to sorb the output of the power developments herein considered will vary throughout the day that the maximum rate of demand for wer will be from two to three times the average.

Storage and pondage.—The flow of a stream may be regulated to ther eliminate daily and seasonal fluctuations or to meet fluctuaons in demand for power which occur throughout the day. In one se the flow of the stream during part of the year is stored to be utized during the remainder of the year. In the other case the flow the stream during one part of the day is stored and utilized during e other part of the day. The former method of regulation is termed torage, the latter pondage.

Pondage, to be effective, must be close to the power plant, while torage may be located upon the river at considerable distances above t. Losses of storage water necessary to affect regulation increase ith the distance of the storage site from the power plant, due to the mpossibility of so regulating the flow of the river as to eliminate rregularities which have their source upon the river between the lace of storage and the plant.

Efficiency of storage as affecting stream regulation.—Two or more power plants upon a stream may be regulated from the same storage, providing that the relative magnitudes of flows at various plants remain constant. The closer the plants lie to each other the better this condition will be satisfied. It will generally hold good for stretches along a river between the junctions of large tributaries, as the magnitude of flow of the stream in these stretches will be the same and subject to the same fluctuations.

The Deschutes below the junction of Crooked River receives the flow from three large streams. These streams are the Metolius River, Warmsprings River, and White River. For purposes of regulation from Crooked River these feeders divide the Deschutes below Crooked River into three sections. The records at Mecca represent flow conditions from the junction of the Metolius to Warmsprings River, while records at Moody represent flow conditions from the junction of White River to the Columbia. There are no records of discharge from gaugings upon the Deschutes between the junctions of Warmsprings River and White River.

The dissimilarity between the relative magnitudes and the distributions of flow of the Deschutes at Mecca and Moody does not permi either storage regulation of the flow of the Metolius-Warmspring section of the river to regulate the flow of the White River-Columbi section or vice versa. No studies have been made to determine th degree of water-flow control which may be attained by regulating th flow of either the Metolius-Warmsprings or White River-Columb section of the river, in conjunction with the flow of the Warmspring White River section, owing to prohibitive railroad relocation cos which become necessary for development of power upon this portio of the river.

The Post Reservoir is located on the Crooked River approximatel 90 miles from its junction with the Deschutes and approximatel 200 miles above Moody. For the Deschutes, storage water at Pos would not regulate for ice conditions such as those which caused th low water flow in January, 1912. However, periods of low wat flow of this character are of short duration. Developed power upo the Deschutes would mean the maintenance of emergency capacity either by pondage or auxiliary installations, to carry over suc periods. For the purposes of this report and from a study of th hydrographs of the river 5,000 acre-feet per month during deman upon storage will be assumed to cover regulation losses.

It will be assumed that seepage losses from the Post Reservoir wil return to the river flow through ground-water storage and that distribution of return flow throughout the year will be constant. Seepag returns to the river during periods of demand upon storage will no be lost to regulation of river flow except in cases where the rate o return flow exceeds the rate of regulation demand upon the storage.

Economic limits of nonstorage development.—In the development of power upon a stream the maximum available from unregulated flow is rarely utilized upon the development of a given fall, but is utilized as the growth of the market demands increased power up to the economic maximum, which is subject not only to the magnitude and distribution of the minimum flow of the river, but also depends upon the character and magnitude of the power market which is served. No investigations have been made to determine the probable limits within which the unregulated flow of the river might be economically developed, and the assumed unregulated flows of the river which are herein used merely indicate limits of flow, as determined from records, within which actual development would probably take place.

COST OF STORAGE POWER AT MOODY.

Modified flow.—The demand during the season from April 1 to April 1 for water from storage sufficient to maintain a continuous modified flow at Moody of 4,700 second-feet, 4,800 second-feet, 4,900 econd-feet, and 5,000 second-feet for the period of record, expressed acre-feet, is as follows:

Season.	4,700 second-feet.	4,800 second-feet.	4,900 second-feet.	5,000 second-feet.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
9-10	14,200	31,780	54,300	77,900
6-7	20,900	38,420	65,340	97,300
7-8	21,000	40,963	68,420	99,[illegible]00
12-13	27,660	48,940	76,340	106,040
13-14	34,800	65,400	80,770	137,900
8-9	44,460	70,310	99,960	142,150
10-11	59,460	86,640	120,150	155,100
11-12	96,620	131,120	167,880	205,[illegible]00
14-15	157,240	204,770	258,140	314,700
Average	53,000	80,000	110,000	148,000

The demand during the season April 1 to April 1, 1914–15, is pproximately two and one-half times the average seasonal demand or the period. In order to provide against a shortage of approximately 50,000 acre-feet during this season, it would be necessary to maintain 70,000 acre-feet of idle reservoir capacity at Post throughout the period of record. An auxiliary installation of 18 horsepower of equipment per 100 horsepower of total installation would provide against this shortage, when such shortage is distributed over thirty 24-hour days.

Conditions of growth and operation of the power development herein considered could require that as much as 40 per cent of the installed capacity be auxiliary equipment located on water transportation and near the center of gravity of the distributing system.

Seventy thousand acre-feet of reservoir capacity at Post will cost approximately $200,000. The annual interest charges upon $200,000 at 6 per cent would be $12,000. For the nine years of the period of record interest charges at the rate of 6 per cent would be approximately $110,000.

The fuel cost of auxiliary steam power, generated from fuel oil at $1.20 per barrel, to cover a shortage of 50,000 acre-feet, would be approximately $160 per foot of fall developed. Approximately 700 feet of fall must be developed on the Deschutes before the fuel cost of auxiliary power, sufficient to cover a shortage of 50,000 acre-feet once in 10 years, would be as large as interest charges for the same period upon the cost of reservoir capacity, necessary to supply storage to carry over periods similar to the period April 1, 1914, to April 1, 1915. Upon the Deschutes, two seasons of low run-off generally occur consecutively. It is probable that the season from October, 1913, to October, 1914, is one whose frequency is less than one in ten.

With a shortage during the season of April 1, 1914, to April 1, 1915, of 50,000 acre-feet of water, it would require at Post a reservoir capacity of 120,000 acre-feet to maintain at Moody a regulated rate of modified flow of 4,700 second-feet, 150,000 acre-feet to maintain 4,800 second-feet, 190,000 acre-feet to maintain 4,900 second-feet, and 250,000 acre-feet to maintain 5,000 second-feet. If the maximum flow which may be utilized without storage is, say, 4,200 second-feet, the usable flow due to storage will be 500 second-feet for a regulated flow of 4,700; 600 second-feet for 4,800 second-feet; 700 for 4,900 second-feet; and 800 second-feet for 5,000 second-feet. The volume of storage flow per thousand acre-feet of reservoir capacity, for a regulated flow of 4,700 second-feet, will be 4.2 second-feet. With a reservoir cost of $4.08 per acre-foot for a capacity of 120,000 acre-feet, the cost of storage flow per second-foot will be $980. If power measured at the switchboard is generated with an efficiency of 80 per cent, the cost of storage power per foot-head horsepower will be $10,800. Likewise the cost of storage power for a regulated flow of 4,800 second-feet will be $10,600; for 4,900 second-feet, $11,000; and for 5,000 second-feet, $11,900.

A regulated flow of 4,850 second-feet at Moody will require a reservoir capacity of 170,000 acre-feet. The estimated cost of a reservoir at Post of 170,000 acre-feet capacity, with a single-arch type of dam, is $3.81 per acre-foot of capacity. The estimated volumes of storage flow per unit of reservoir capacity and estimated reservoir costs per second-foot of storage flow, together with the costs of storage power per foot-head horsepower at 80 per cent efficiency, are as follows:

MOODY.

[Regulated rate of modified flow, 4,850 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Volume of storage flow per thousand acre-feet of reservoir capacity.	Reservoir cost per second-foot of storage flow.	Cost of storage power per foot-head horsepower.
Second-feet.	*Second-feet.*	*Second-feet.*		
4,000	850	5.00	$760	$8,350
4,100	750	4.41	860	9,500
4,200	650	3.83	1,000	11,000
4,300	550	3.23	1,180	13,000
4,400	450	2.65	1,440	15,900

The estimated developed fall required on the lower portion of the Deschutes from White River to the Columbia, in order to be able to develop storage power from the estimated modified flow of the lower Deschutes, with reservoir costs of from $30 to $70 per horsepower, at 80 per cent efficiency, is as follows:

MOODY.

[Regulated rate of modified flow, 4,850 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Reservoir cost per developed storage horsepower.				
		$30.	$40.	$50.	$60.	$70.
		Feet of fall.				
Sec.-ft.	*Sec.-ft.*					
4,000	850	280	210	165	140	120
4,100	750	315	240	190	160	135
4,200	650	370	275	220	180	155
4,300	550	430	325	260	220	185
4,400	450	530	400	320	265	230

The following table indicates possible manipulation of storage in eservoir of 170,000 acre-feet capacity at Post in order to regulate e assumed modified flow of the Deschutes at Moody to a minimum w of 4,850 second-feet for the period from 1906 to 1915.

In column B is shown the mean monthly flow in second-feet at ody as recorded.

In column C is shown the probable natural mean monthly flow in cond-feet at Moody as it would have occurred providing there had en no diversion of water on the upper Deschutes.

In column D is shown the probable modified mean monthly flow second-feet of the Deschutes at Moody as it would have occurred the assumption that the entire flow of the Deschutes above Benm Falls, together with the flow of Tumalo Creek, was diverted for rigating purposes.

In column E is shown the estimated and recorded monthly run-off acre-feet of Crooked River at Post.

In column F is given, in acre-feet, the monthly demand on storage Post for water that would have been required to maintain a inimum continuous flow at Moody of 4,850 second-feet, together ith that necessary to irrigate 5,000 acres of Crooked River bottom nds.

In column G are given, in acre-feet, the assumed losses of water y evaporation and seepage from the reservoir at Post, together ith the assumed losses of water required to maintain regulation of ow at Moody.

In column H is given, in acre-feet, the estimated volume of water tored in the reservoir at Post at the beginning of the calendar onth.

In column I is given, in acre-feet, the overflow of water from the servoir at Post, together with the shortage of storage water necesary to maintain the assumed regulation of flow at Moody.

Estimated manipulation of storage at Post to regulate the flow of the Deschutes for po development at Moody.

A	B	C	D	E	F	G	H	I
Date.	Recorded flow of Deschutes River at Moody.	Probable natural flow of Deschutes River at Moody.	Probable modified flow of Deschutes River at Moody.	Reservoir inflow from Crooked River at Post.	Storage demand to maintain 4,850 second-feet continuous flow at Moody.	Seepage, evaporation and regulation losses.	Water stored at Post at beginning of month.	Overflo and shortag
1906	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft*
October	5,180	5,430	4,580	2,400	17,000	5,160	30,020	....
November	7,290	7,300	6,160	7,430	12,500	5,080	10,260	....
December	6,720	6,760	5,650	11,250	6,360	5,000	110	....
1907.								
January	6,720	6,680	5,520	12,900	1,500	5,000	....	....
February	13,900	13,900	9,600	92,000	500	5,050	6,400	(1
March	9,590	9,650	6,600	92,000	....	3,270	92,850	11,
April	11,900	12,100	8,560	86,000	....	4,700	170,000	81,
May	8,950	9,220	6,580	30,000	[2] 1,600	3,100	170,000	25,
June	7,250	7,620	5,510	5,050	[2] 2,900	2,400	170,000	....
July	6,230	6,540	4,830	1,470	[2] 15,450	7,880	169,750	....
August	5,670	6,000	4,610	1,470	[2] 16,850	8,150	147,890	....
September	5,660	5,900	4,610	1,490	[2] 14,650	7,000	124,360	....
October	5,660	5,870	4,710	2,640	8,540	5,760	104,200	....
November	5,980	6,070	4,910	6,350	2,300	5,350	92,540	....
December	8,720	8,730	7,330	9,050	....	2,300	91,240	....
1908.								
January	7,420	7,390	6,060	8,000	120	5,000	97,990	....
February	6,110	6,070	4,940	9,750	300	5,380	100,870	....
March	8,600	8,600	6,720	48,200	2,400	6,140	104,940	(1)
April	8,510	8,650	6,310	51,670	....	4,550	144,600	21,7
May	7,340	7,580	5,760	15,700	[2] 1,600	3,100	170,000	11,0
June	6,500	6,840	5,120	4,820	[2] 3,000	2,400	170,000	....
July	6,000	6,450	4,880	1,720	[2] 3,350	2,880	169,420	....
August	5,400	5,810	4,640	860	[2] 15,250	7,960	164,910	....
September	5,300	5,620	4,510	1,190	[2] 21,050	7,250	142,560	....
October	5,300	5,540	4,340	2,950	23,500	5,800	115,450	....
November	5,970	5,970	4,850	5,060	....	2,650	89,100	....
December	5,710	5,670	4,710	4,930	9,910	5,000	91,510	....
1909.								
January	7,470	7,390	6,090	11,600	8,720	5,000	81,530	....
February	7,180	7,150	5,880	21,900	9,070	5,280	79,410	....
March	7,520	7,550	5,830	43,000	....	3,250	86,960	(1)
April	8,390	8,560	6,420	56,800	....	4,400	126,710	9,1
May	7,040	7,380	5,770	19,300	[2] 1,600	3,100	170,000	14,0
June	6,760	7,160	5,660	4,400	[2] 2,900	2,400	170,000	....
July	5,580	5,890	4,720	2,450	[2] 6,290	7,880	169,100	....
August	5,260	5,660	4,630	1,160	[2] 15,470	7,800	157,380	....
September	5,360	5,640	4,620	2,010	[2] 14,500	7,090	135,270	....
October	5,540	5,730	4,730	3,440	7,350	5,800	115,690	....
November	9,380	9,320	7,230	25,600	3,750	5,360	105,980	....
December	8,710	8,630	6,930	13,200	....	2,300	122,470	....
1910.								
January	9,420	9,360	7,980	21,600	....	2,300	133,370	(1)
February	8,710	8,050	6,290	38,300	....	2,750	152,670	18,2
March	14,300	14,300	10,780	117,000	....	3,740	170,000	113,2
April	8,740	8,930	6,810	35,500	....	4,700	170,000	30,8
May	7,960	8,250	6,510	9,350	[2] 1,600	3,100	170,000	4,6
June	6,320	6,750	5,450	916	[2] 2,900	2,400	170,000	....
July	5,400	5,870	4,770	1,060	[2] 9,050	7,880	165,620	....
August	5,180	5,490	4,490	633	[2] 24,950	8,150	149,750	....
September	5,230	5,520	4,540	1,660	[2] 19,800	7,000	117,280	....
October	5,290	5,490	4,510	2,840	21,500	5,660	92,140	....
November	6,300	6,300	5,240	6,070	7,000	5,280	67,820	....
December	6,820	6,830	5,510	16,800	....	2,300	61,610	....
1911.								
January	6,350	6,300	5,270	8,980	5,460	5,000	75,110	....
February	5,710	5,650	4,650	9,660	5,050	5,300	73,630	....
March	7,210	7,180	5,290	62,700	17,100	5,900	72,940	....
April	7,450	7,630	5,810	45,800	1,310	7,000	112,640	....
May	6,810	7,160	5,680	14,800	[2] 1,600	2,950	150,130	....
June	6,380	6,820	5,420	2,550	[2] 4,090	7,300	160,380	....

[1] Overflow.

[2] Includes diversion demand for 5,000 acres of Crooked River bottom lands.

stimated manipulation of storage at Post to regulate the flow of the Deschutes for power development at Moody—Continued

A	B	C	D	E	F	G	H	I
Date.	Recorded flow of Deschutes River at Moody.	Probable natural flow of Deschutes River at Moody.	Probable modified flow of Deschutes River at Moody.	Reservoir inflow from Crooked River at Post.	Storage demand to maintain 4,850 second-feet continuous flow at Moody.	Seepage, evaporation and regulation losses.	Water stored at Post at beginning of month.	Overflow and shortage.
1911.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
ly	5,260	5,740	4,700	806	[1] 15,880	7,700	151,540	....
ugust	4,850	5,250	4,410	762	[1] 29,800	7,940	128,770	....
ptember	4,930	5,220	4,360	990	[1] 28,750	6,600	91,790	....
ctober	4,990	5,180	4,330	2,870	23,750	5,540	57,430	....
ovember	5,440	5,440	4,560	3,660	18,660	5,180	31,010	(2)
ecember	5,340	5,270	4,470	4,550	19,750	5,000	10,830	9,370
1912.								
nuary	7,940	7,870	6,700	19,800	16,750	5,000	....	1,950
ebruary	9,720	9,670	8,040	36,100	....	2,300	....	....
arch	6,020	6,890	5,680	20,400	....	2,840	33,800	....
pril	9,550	9,610	7,240	76,200	....	3,500	51,360	(3)
ay	9,770	10,060	7,340	73,300	[1] 1,600	2,700	124,060	23,000
une	7,980	8,440	6,380	16,400	[1] 7,870	7,400	170,000	1,130
uly	5,910	6,400	5,010	3,800	[1] 6,340	7,880	170,000	....
ugust	5,390	5,830	4,650	1,870	[1] 16,120	7,890	159,580	....
eptember	5,520	5,820	4,660	1,870	[1] 14,710	7,100	137,440	....
ctober	5,480	5,710	4,620	2,780	14,300	7,000	117,500	....
ovember	6,030	6,140	4,980	4,700	4,250	5,360	98,980	....
ecember	6,000	5,940	4,860	6,950	7,110	5,000	94,070	....
1913.								
anuary	6,800	6,830	5,730	6,060	....	2,300	88,910	....
February	6,440	6,470	5,370	10,000	....	2,630	92,670	....
March	7,070	7,120	5,630	35,400	1,170	6,080	100,040	(3)
April	10,600	10,870	7,940	96,500	....	4,350	128,190	50,340
May	8,330	8,730	6,720	31,620	1,600	3,100	170,000	26,920
June	7,330	8,060	6,290	3,610	2,900	2,400	170,000	....
July	6,050	6,750	5,300	2,400	3,950	7,880	168,310	....
August	5,100	5,890	4,700	2,030	12,400	8,290	158,880	....
September	5,030	5,740	4,630	1,130	14,060	7,150	140,220	....
October	5,310	5,780	4,680	3,440	10,070	5,800	120,140	....
November	5,550	5,790	4,640	5,530	14,420	5,380	107,710	....
December	5,540	5,610	4,610	4,570	21,950	5,000	93,440	....
1914.								
January	6,710	6,760	5,580	12,900	3,470	5,000	71,060	....
February	6,210	6,270	4,950	22,300	8,700	5,300	75,490	....
March	9,700	9,760	7,240	85,600	....	3,260	83,790	(3)
April	8,530	8,810	6,300	74,620	....	4,700	166,130	66,050
May	6,300	6,940	5,370	17,900	1,780	7,400	170,000	8,720
June	5,370	6,110	4,860	6,730	5,150	7,400	170,000	....
July	4,860	5,600	4,690	2,000	20,020	7,820	164,180	....
August	4,460	5,260	4,490	400	24,300	7,940	138,340	....
September	4,610	5,220	4,390	1,230	28,250	6,900	106,500	....
October	4,990	5,220	4,370	3,080	29,200	5,620	72,580	....
November	5,260	5,420	4,550	5,950	17,700	5,230	40,840	(2)
December	4,870	4,920	4,000	6,150	44,500	5,000	23,860	19,490
1915.								
January	5,070	5,300	4,270	6,150	32,500	....	....	26,350
February	5,320	5,500	4,590	8,320	18,900	....	....	10,580
March	6,400	....	....	30,000	20,000	5,000	....	....

---

[1] Includes diversion demand for 5,000 acres of Crooked River bottom lands. [2] Shortage. [3] Overflow.

Recorded flow at Moody.—In the development of irrigation in the upper Deschutes Basin it is possible that either the actual use would not correspond to the assumptions herein made or that power may be developed to such a point that its derivation from storage would become a possibility before the entire diversion of the flow of the upper Deschutes for irrigating purposes has taken place. In this event the flow on the lower Deschutes would be such that it would be represented by conditions of flow, lying between the recorded and assumed modified flows at Moody, for the period of record.

For the period of record it is estimated that a minimum cost of storage flow to regulate the recorded flow of the Deschutes at Moody, with provision for a shortage of 50,000 acre-feet of storage during season April 1, 1914, to April 1, 1915, provides a maximum continuous flow on the lower Deschutes of 5,100 second-feet.

For this degree of regulation a reservoir capacity of 150,000 acre-feet is required. The estimated cost of a reservoir at Post of 150,000 acre-feet capacity, with a single arch type of dam, is $3.85 per acre-foot. The estimated volumes of storage flow per unit of reservoir capacity and estimated reservoir costs per second-foot of storage flow, together with the costs of storage power per foot-head horsepower at 80 per cent efficiency, are as follows:

MOODY.

[Regulated rate of recorded flow, 5,100 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Volume of storage flow per thousand acre-feet reservoir capacity.	Reservoir cost per second-foot of storage flow.	Cost of storage power per foot-head horsepower.
Second-feet.	*Second-feet.*	*Second-feet.*		
4,500	600	4.00	$960	$10,600
4,600	500	3.33	1,150	12,700
4,700	400	2.66	1,440	15,800
4,800	300	2.00	1,925	21,200

The estimated developed head required on the lower portion of the Deschutes from White River to the Columbia, in order to be able to develop storage power from the flow of the river as recorded, with reservoir costs of from $30 to $70 per horsepower at 80 per cent efficiency, is as follows:

MOODY.

[Regulated rate of recorded flow, 5,100 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Reservoir cost per developed storage horsepower.				
		$30.	$40.	$50.	$60.	$70.
		Feet of fall.				
Sec.-ft.	*Sec.-ft.*					
4,500	600	350	265	210	175	130
4,600	500	420	320	250	210	180
4,700	400	530	400	315	260	225
4,800	300	700	530	425	350	300

ESTIMATED COST OF STORAGE POWER AT MECCA.

Modified flow.—Records of flow of the Deschutes at Mecca have en maintained since 1911.

The demand, during the season from April 1 to April 1, for water m storage, sufficient to maintain a continuous modified flow at cca of 3,900 second-feet, 4,000 second-feet, and 4,100 second-feet, the period of record, expressed in acre-feet, is as follows:

Season.	Continuous modified flow.		
	3,900 second-feet.	4,000 second-feet	4,100 second-feet.
	Acre-ft.	*Acre-ft.*	*Acre-ft.*
-14	17,800	52,150	82,300
-15	24,900	64,100	115,100
-13	78,300	120,800	160,800
-12	152,250	199,650	247,050
Average	68,300	109,200	151,300

The period is so short that it is not possible to determine the aximum annual demand upon storage with a frequency of one in n or more, with any degree of certainty, and particularly so as ither the discharges nor the estimated demands upon storage at ecca and Moody appear to have the same relative magnitude.

A continuous regulated rate of modified flow at Mecca of 4,050 second-feet, with allowance for a shortage of 40,000 acre-feet during the ason of 1911–12, requires reservoir capacity at Post of 170,000 acre-et. The estimated cost of a reservoir of 170,000 acre-feet capacity t Post, with a single-arch type of dam, is $3.78 per acre-foot of apacity.

The estimated volumes of storage flow, per unit of reservoir apacity, and estimated reservoir costs per second-foot of storage ow, together with costs of storage power per foot head horsepower t 80 per cent efficiency are as follows:

MECCA.

[Regulated rate of modified flow, 4,050 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Volume of storage flow per thousand acre-feet reservoir capacity.	Reservoir cost per second-foot of storage flow.	Cost of storage power per foot fall horsepower.
Second-feet.	*Second-feet.*	*Second-feet.*		
3,400	650	3.82	$1,000	$11,000
3,500	550	3.23	1,180	13,000
3,600	450	2.65	1,440	15,900
3,700	350	2.06	1,860	20,400

The estimated developed fall required on the upper portion of th lower Deschutes from Metolius River to Mecca before storage pow can be developed from the modified flow of the river, with reservo cost of from $20 to $60 per horsepower, at 80 per cent efficiency, as follows:

MECCA.

[Regulated rate of modified flow, 4,050 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Reservoir cost per developed horsepower.				
		$20.	$30.	$40.	$50.	$60.
		Feet of fall.				
Second-feet.	*Sec.-feet.*					
3,400	650	550	370	275	220	180
3,500	550	650	430	325	260	220
3,600	450	800	530	400	320	265
3,700	350	1,040	680	520	410	340

Recorded flow.—A continuous regulated rate of recorded flow a Mecca of 4,700 second feet, with allowance for a shortage of 40,00 acre-feet during the season of 1911–12, requires reservoir capacity a Post of 170,000 acre-feet.

The estimated cost of a reservoir of 170,000 acre-feet capacity a Post, with a single-arch type of dam, is $3.78 per acre-foot of capacity

Estimated volumes of storage flow per unit of reservoir capacit and estimated reservoir costs per second-foot of storage flow, togeth with costs of storage power per foot fall horsepower, at 80 per cen efficiency, are as follows:

MECCA.

[Regulated rate of recorded flow, 4,700 second-feet.]

Rate of nonstorage flow.	Rate of storage flow.	Volume of storage flow per thousand acre-feet reservoir capacity.	Reservoir cost per second-foot of storage flow.	Cost of storage power per foot fall horsepower.
Second-feet.	*Second-feet.*	*Second-feet*		
3,800	900	5.30	$720	$7,900
3,900	800	4.70	810	8,900
4,000	700	4.12	925	10,200
4,100	600	3.53	1,080	11,900

The estimated developed fall required on the upper portion of the lower Deschutes, from Metolius River to Mecca, before storage power can be developed from the recorded flow of the river, with reservoir costs of from $20 to $60 per horsepower at 80 per cent efficiency, is as follows:

MECCA.

[Regulated rate of recorded flow.]

Rate of nonstorage flow.	Rate of storage flow.	Reservoir cost per developed horsepower (80 per cent efficiency).				
		$20	$30	$40	$50	$60
		Feet of fall.				
Sec.-ft.	*Sec.-ft.*					
3,800	900	395	260	200	160	130
3,900	800	445	295	220	180	150
4,000	700	510	340	255	200	170
4,100	600	595	400	300	240	200

POWER SITES ON THE DESCHUTES.

Fourteen possible power sites upon the Deschutes, below the junction of Crooked River, are described in the report upon Deschutes River (United States Geological Survey, Water Supply Paper No. 344, pp. 124–132, 173), with combined gross developable fall of 1,406 feet. The available future flow which may be developed is estimated to vary rom 3,400 second-feet at the upper sites to 4,500 second-feet at the ower sites. Of these sites, there are six only which may be developed without elevating the tracks of one or both of the railroads which run up the Deschutes. Three of these sites, the Moody, Reclamation, and Sherar Falls, are located on the Deschutes between White River and the Columbia, and have an estimated developable fall of 324 feet and modified flow of 4,500 second-feet. The three other sites, the Mecca, Pelton, and Metolius, are located upon the Deschutes, immediately below the junction of Crooked River with it, and have an estimated developable fall of 360 feet and modified flow of 3,400 second-feet.

Estimated fall cost of power development.—In order to utilize the entire normal minimum flow of a stream, not only must pondage be provided to store water during hours of minimum power demand for use during hours of maximum demand, but also sufficient equipment must be installed to transform and deliver energy at the maximum rate of demand.

For purposes of this report, an installed capacity of equipment, including auxiliary equipment, steam or otherwise, of two and one-half times the average power output—that is, provision for a load factor of 40 per cent—will be used in estimates of cost of power development on the Deschutes. The cost of installation of steam or other auxiliary equipment will be assumed to be approximately the same as that of equipment for hydraulic installation.

For purposes of this report the six power sites above mentioned wil alone be considered for possible preliminary development of powe upon the Deschutes.

The physical characteristics of these sites are as follows:

WHITE RIVER-COLUMBIA SECTION OF DESCHUTES RIVER.

Power site.	Gross fall.	Area of pondage.	Developable pow per se on foot of flo at 80 per cent efficiency.
	Feet.	*Acres.*	*Horse-power.*
Moody	132	910	12
Reclamation	92	430	8.
Sherar Falls	100	170	9.

METOLIUS-WARM SPRINGS SECTION OF DESCHUTES RIVER.

Power site.	Gross fall.	Area of pondage.	Developable pow per se on foot of flo at 80 per cent efficiency.
Mecca	90	800	8.
Pelton	60	110	5.
Metolius	210	210	19.

For profiles of the several dam sites, see report upon Deschute River and its Utilization, United States Geological Survey, Wate Supply Paper No. 344.

In general, the cost of a dam per unit of power output will var inversely as the quantity of power developed, while the cost o power per unit of output for forebays, penstocks, power houses and equipment will remain constant as the quantity of power developed varies.

The estimated cost of developing fall on the White River-Columbi section of the Deschutes, with 4,500 second feet flow at the Moody Reclamation, and Sherar Falls power sites, is $50 per horsepower.

The estimated cost of developing fall on the Metolius-Warm Springs section of the Deschutes, with 3,400 second-feet flow at the Mecca, Pelton, and Metolius power sites, is $35 per horsepower.

Relative cost of fall and storage power.—It is estimated that the cost of developing fall upon the White River-Columbia sections o the Deschutes, at the Moody, Reclamation, and Sherar Falls powe sites is $50 per horsepower. The combined fall of these power sites is 324 feet. With a developable rate of modified flow of 4,000 second-feet upon this section of the river, it requires that approximately 165 feet of fall be developed, before the reservoir cost of storage power drops to $50 per horsepower. Likewise for 4,100 second-feet modified flow, it will require approximately 190 feet of fall; for 4,200 second-feet flow, 220 feet of fall; for 4,300 second-feet flow, 260 feet of fall; and for 4,400 second-feet flow, 320 feet of fall, before the reservoir cost of storage power drops to $50 per horsepower.

With a developed rate of recorded flow of 4,500 second-feet upon his section of the river, it requires that approximately 210 feet of all be developed before the reservoir cost of storage power drops to 50 per horsepower. Likewise for 4,600 second-feet of recorded flow t requires approximately 250 feet of fall, for 4,700 second-feet 315 feet of fall, and for 4,800 second-feet 425 feet of fall before the reservoir cost of storage power drops to $50 per horsepower.

It is estimated that the cost required to develop fall upon the Metolius-Warm Springs section of the Deschutes at the Mecca, Pelton, and Metolius power sites is $35 per horsepower. The combined fall of these power sites is 360 feet. With a developed rate of modified nonstorage flow of 3,400 second-feet upon this section of the river it requires that approximately 325 feet of fall be developed before the reservoir cost of storage power drops to $35 per horsepower. Likewise for 3,500 second-feet modified nonstorage flow it requires approximately 375 feet of fall; for 3,600 second-feet flow, 410 feet of fall; and for 3,700 second-feet flow, 600 feet of fall before the reservoir cost of storage power drops to this amount.

With a developed rate of recorded flow of 3,800 second-feet upon this section of the river it requires that approximately 230 feet of fall be developed before the reservoir cost of storage power drops to $35 per horsepower. Likewise for 3,900 second-feet of recorded flow it requires approximately 260 feet of fall; for 4,000 second-feet flow, 300 feet of fall; and for 4,100 second-feet flow, 350 feet of fall before the reservoir cost of storage power drops to this amount.

Finally the cost of storage power decreases and increases either as the fall developed increases and decreases or as the developed nonstorage flow decreases and increases.

The economic comparison of storage power with nonstorage power as presented in this report is made upon the basis of comparison of fixed capital invested. A complete presentation of the subject would require that a comparison of the circulating or operating capital invested be also made. The presentation of the subject as a whole would require that the comparison be made upon the basis of maximum returns upon capital invested.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.

SUMMARY.

A summary in the form of a brief résumé or synopsis appears in the first pages of the report.

CONCLUSIONS.

It appears from the investigations—

1. That the Ochoco project to serve the equivalent of 15,500 acres of land is feasible at the estimated cost of $51.30, if interest charges do not exceed 3 or 4 per cent per annum; that is, if the credit of the State or Nation is used in financing the project.

2. That a water use of 1.85 acre-feet per acre of irrigable land, delivered to each 40-acre tract, is sufficient on the assumption that at least one-third of the project will be in grains.

3. That the water supply would have been sufficient during the past 12 years, including the present year, which will probably be the lowest for 26 years, to have furnished practically a full supply 8 years of the 12; that of the remaining 4 years, the shortage in 2 would not have exceeded 30 per cent, and in the remaining 2, the shortage would have been approximately 40 and 55 per cent, respectively.

4. That the cost of the project can probably be borne by the land if interest charges on capital borrowed for construction do not exceed 3 to 4 per cent.

5. That storage can be provided on Crooked River, at Post Reservoir site, at a cost of approximately $3.50 per acre-foot, or about one-fourth that for Ochoco Reservoir.

6. That there is water supply from Crooked River sufficient for about 45,000 acres of land of the North unit of the Deschutes project and the lands of the Ochoco project, but that in either case the lands can be more cheaply served from other sources.

7. That the Post Reservoir storage will not be economically applicable to regulation of lower Deschutes River until from 200 to 300 feet of power head has been developed below the mouth of Metolius River.

RECOMMENDATIONS.

It is recommended:

(*a*) That it be the policy of the United States and the State to treat the Ochoco project as a possible future project;

(*b*) That unappropriated waters of Ochoco Creek be held withdrawn by the State and that any unpatented lands necessary to construction of Ochoco Reservoir be held withdrawn from entry;

(*c*) That the gaging station for measuring the flow of Ochoco Creek be maintained for a sufficient number of years to check the estimates herein presented;

(*d*) That the unpatented irrigable lands, of which at most there but a few portions of 40-acre tracts, remain open to entry;

(*e*) That it be the policy of the United States and the State to at the use of Crooked River for either irrigation or power purposes so remote as to be practically infeasible;

f) That all waters of Crooked River, except Ochoco Creek, be de available for appropriation; and that unpatented lands hereore withdrawn from entry for Post Reservoir site be restored to ry.

LAND AND WATER WITHDRAWALS.

In compliance with the terms of the agreement of May 5, 1913, public lands not otherwise disposed of, shown on Plate No. 30, ve been recommended to be withdrawn from entry by the Secretary the Interior.

Under date of April 8, 1914, the unappropriated waters of Ochoco eek to the extent of 50,000 acre-feet were withdrawn from appropriation by the State engineer in compliance with the agreement of y 5, 1913, and on the same date 300,000 acre-feet of the waters Crooked River were withdrawn for storage in the proposed reserir above Post.

COST OF INVESTIGATIONS FOR THIS REPORT.

Following is distribution and total cost of investigations to April 30, 15. The estimated cost during the month of May, undistributed, d of printing this report is $950:

Summary of work and cost to Apr. 30, 1915.

	Paid by United States.	Paid by Oregon.
eam gaging		$392.55
pography and surveys	$1,100.82	1,046.30
oked River dam-site borings	327.55	812.80
hoco dam-site borings	396.98	679.08
mputations, drawings, and publication	248.28	780.08
Total	2,073.63	3,710.81

The apparent difference in contribution by the United States and e State of Oregon in the cost of investigations consists mainly in e investment of the United States in equipment and the cost of inting the report by the Government Printing Office, the exact nount not being determined at this time.

Details of cost.

	Paid by United States.	Paid Oreg
TOPOGRAPHY AND SURVEYS.		
General engineering and administration	$267.00	[illegible]
Services, field work	491.92	[illegible]
Services, office	180.00	[illegible]
Supplies	9.82	[illegible]
Teams and teamsters		[illegible]
Camp maintenance	30.00	[illegible]
Equipment depreciation	50.00	
Preparatory charges	72.08	[illegible]
Soil survey		[illegible]
	1,100.82	[illegible]
CROOKED RIVER DAM-SITE BORINGS.		
General engineering and administration	75.00	[illegible]
Drill labor	66.00	[illegible]
Supplies	2.30	[illegible]
Equipment depreciation	40.00	
Carbon loss	62.25	
Teams and teamsters		[illegible]
Camp maintenance	32.00	[illegible]
Preparatory charges	40.00	[illegible]
Erecting and moving drill	10.00	[illegible]
	327.55	[illegible]
OCHOCO DAM-SITE BORINGS.		
General engineering and administration	90.00	[illegible]
Drill labor	157.40	[illegible]
Supplies	2.33	[illegible]
Equipment depreciation	40.00	
Carbon loss	62.25	
Teams and teamsters		[illegible]
Camp maintenance	17.40	[illegible]
Preparatory charges	24.00	[illegible]
Erecting and moving drill	3.60	[illegible]
	396.98	[illegible]
COMPUTATIONS, DRAWINGS, PUBLICATION, ETC.		
Services	228.33	[illegible]
Supplies	19.95	
	248.28	[illegible]

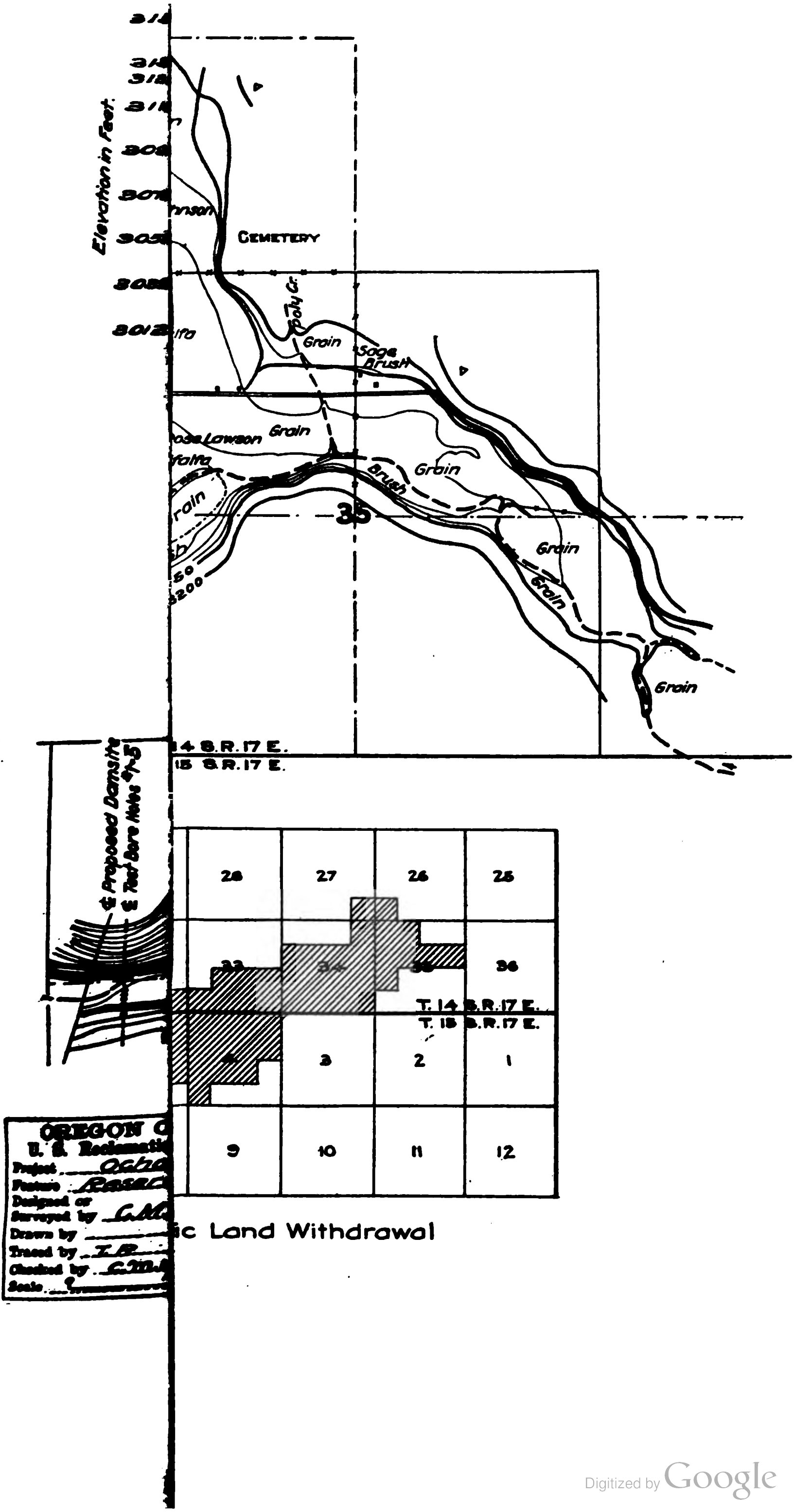
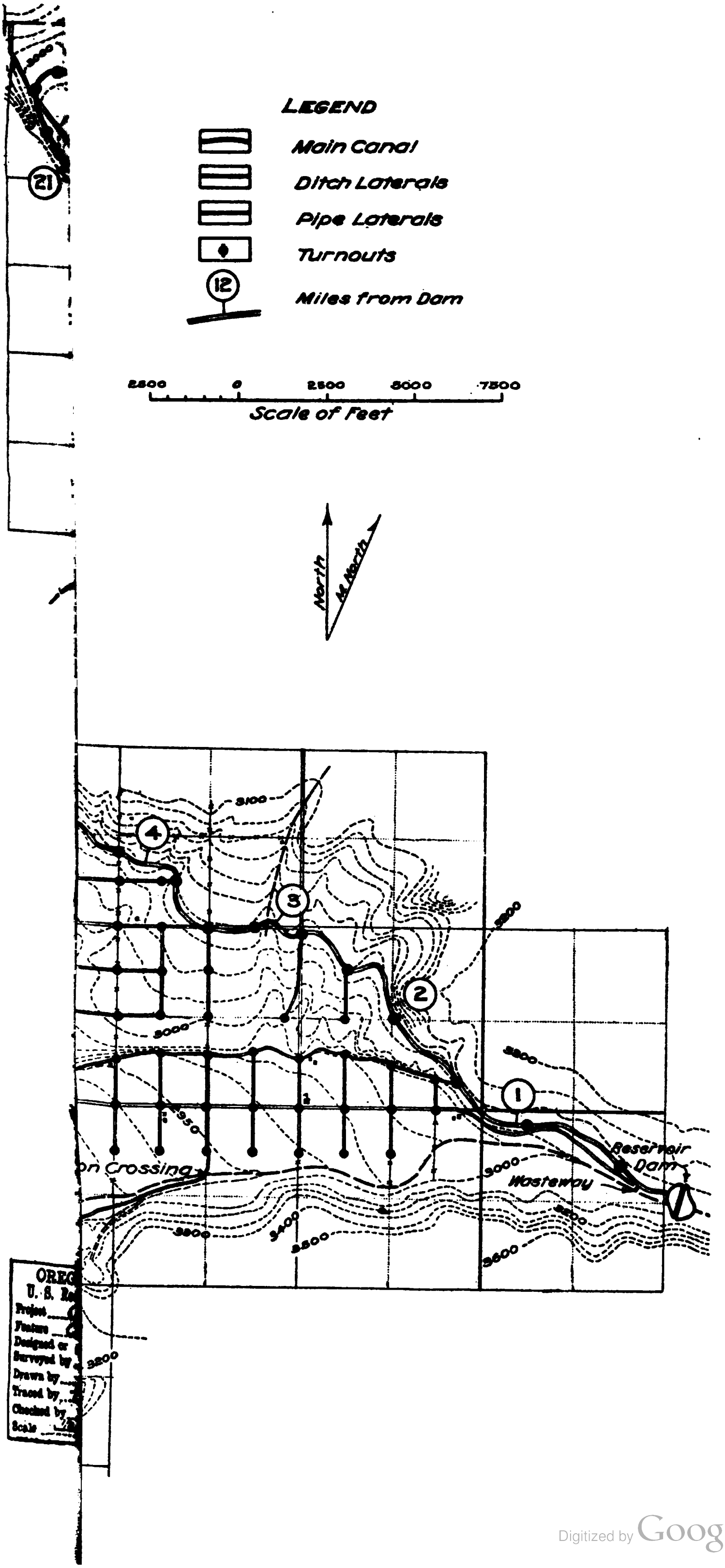

Elevation in Feet
Cemetery
Poly Cr.
Grain
Sage Brush
ose Lawson
Grain
falfa
Grain
Brush
Grain
35
Grain
Grain
Grain
50
200
14 S.R. 17 E.
15 S.R. 17 E.
℄ Proposed Damsite
℄ Test Bore Holes
28
27
26
25
33
34
35
36
T. 14 S.R. 17 E.
T. 15 S.R. 17 E.
4
3
2
1
9
10
11
12
ic Land Withdrawal
OREGON C
U. S. Reclamati
Project
Feature
Designed or Surveyed by
Drawn by
Traced by
Checked by
Scale

Plate 31


LEGEND
Main Canal
Ditch Laterals
Pipe Laterals
Turnouts
12
Miles from Dam
2500
0
2500
5000
7500
Scale of Feet
North
M. North
21
4
3
2
1
3100
3000
3000
2950
2900
2900
3000
3200
3300
3300
3400
3500
3600
3200
on Crossing
Reservoir Dam
Wasteway
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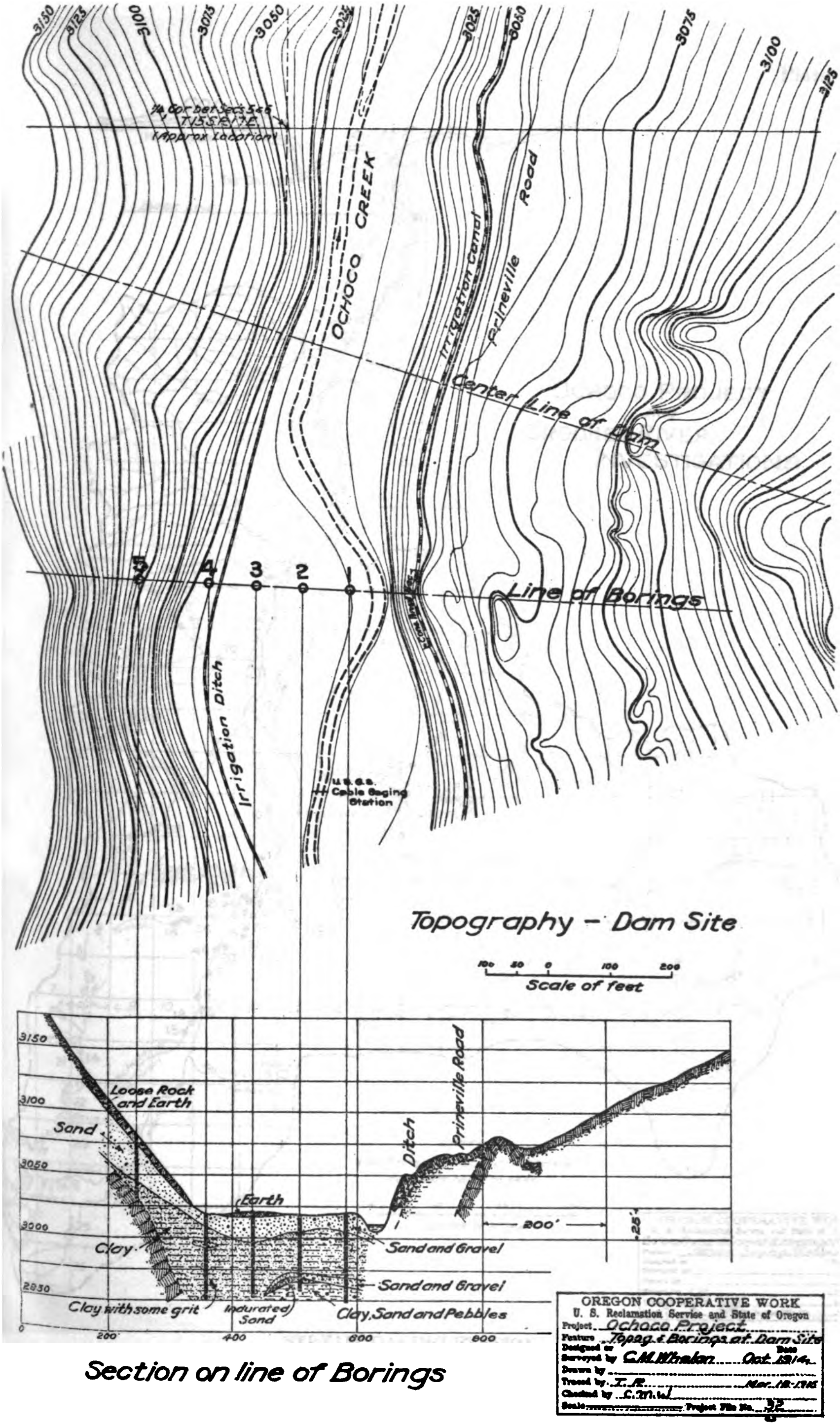
U. S. Re
Project
Feature
Designed or
Surveyed by
Drawn by
Traced by
Checked by
Scale

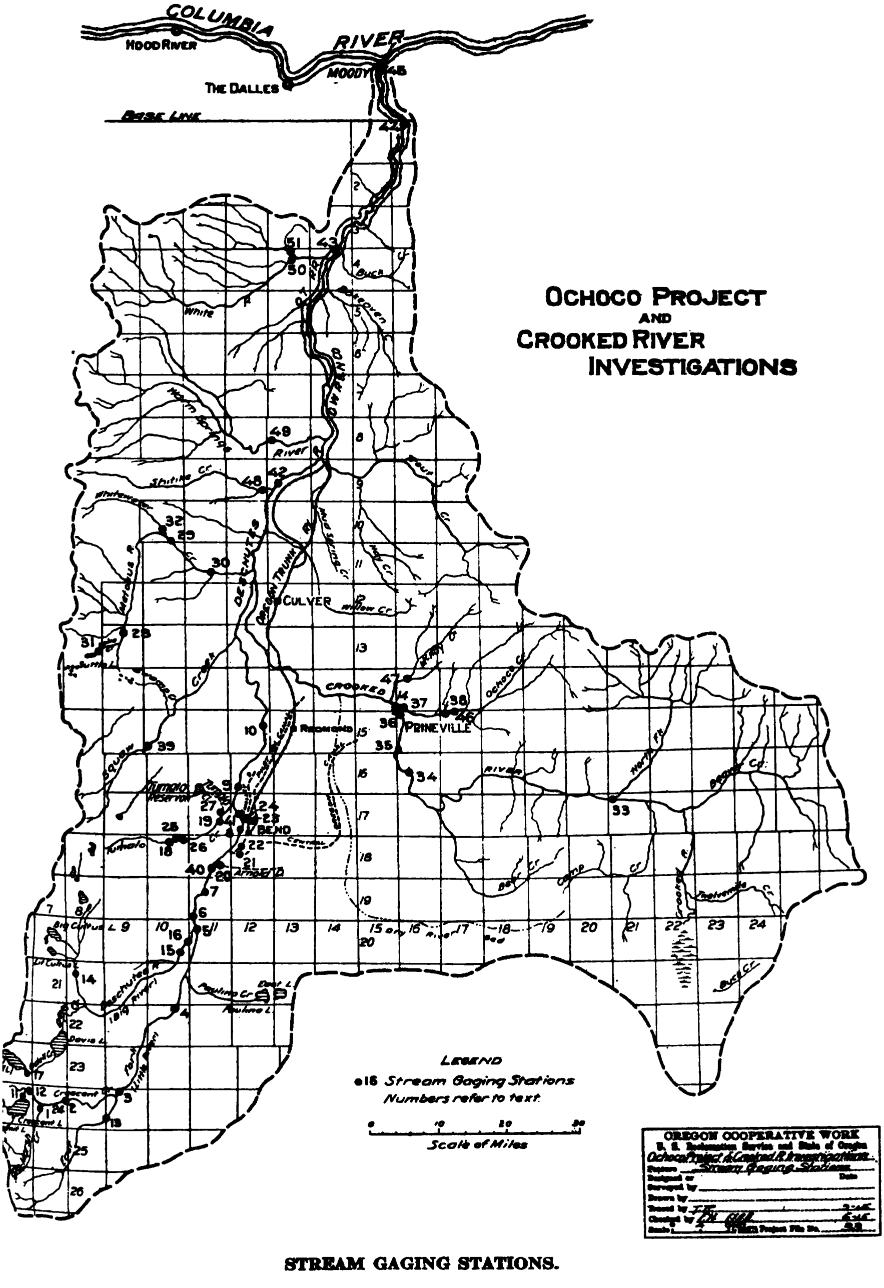
Plate 32



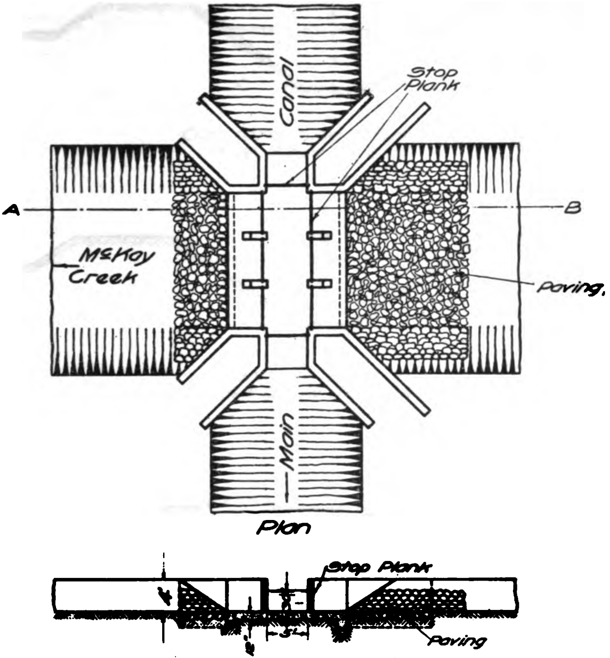
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Ochoco Project
Feature Topog. & Borings at Dam Site
Designed or Surveyed by C.M. Whalen Date Oct. 1914.
Drawn by
Traced by I. R. Mar. 18-1915
Checked by C.M.W.
Scale Project File No. 32

TOPOGRAPHY AND BORINGS AT DAM SITE.

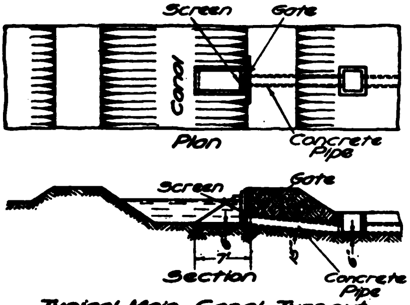
Plate 33



STREAM GAGING STATIONS.



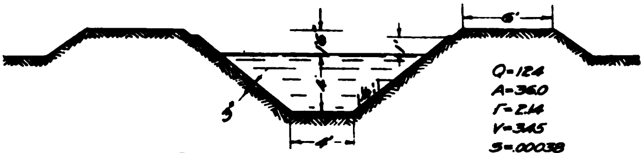
Section on Line A-B
McKoy Creek Grade Crossing



Typical Main Canal Turnout

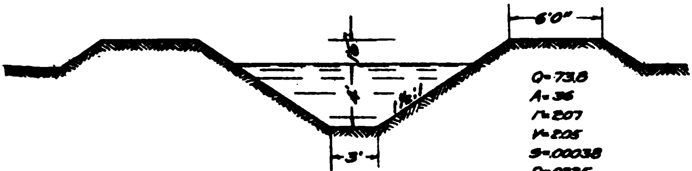
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Ochoco
Feature Canal Sections and Structures
Designed or Date
Surveyed by C.M.Whelan
Drawn by P.A.H.
Traced by "
Checked by C.E.A.B.
Scale 1 ______ feet Project File No. 36

CANAL SECTIONS AND STRUCTURES.



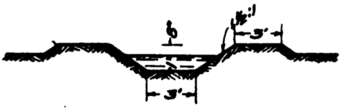
Concrete Lined Section
Mile 5.3 to Mile 7.0

Q=124
A=36.0
r=2.14
V=3.45
S=.00038
n=.014



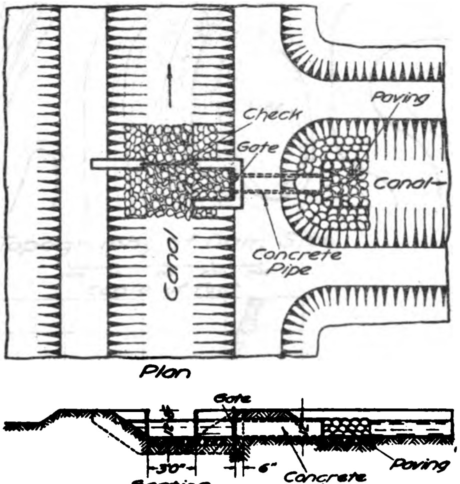
Unlined Section
Mile 13.2 to Mile 13.83

Q=73.8
A=36
r=2.07
V=2.05
S=.00038
n=.0225



Typical 10 Sec. Foot Lateral

Q=10.2
A=4.50
r=0.68
V=2.26
S=.003
n=.025



Plan

Section

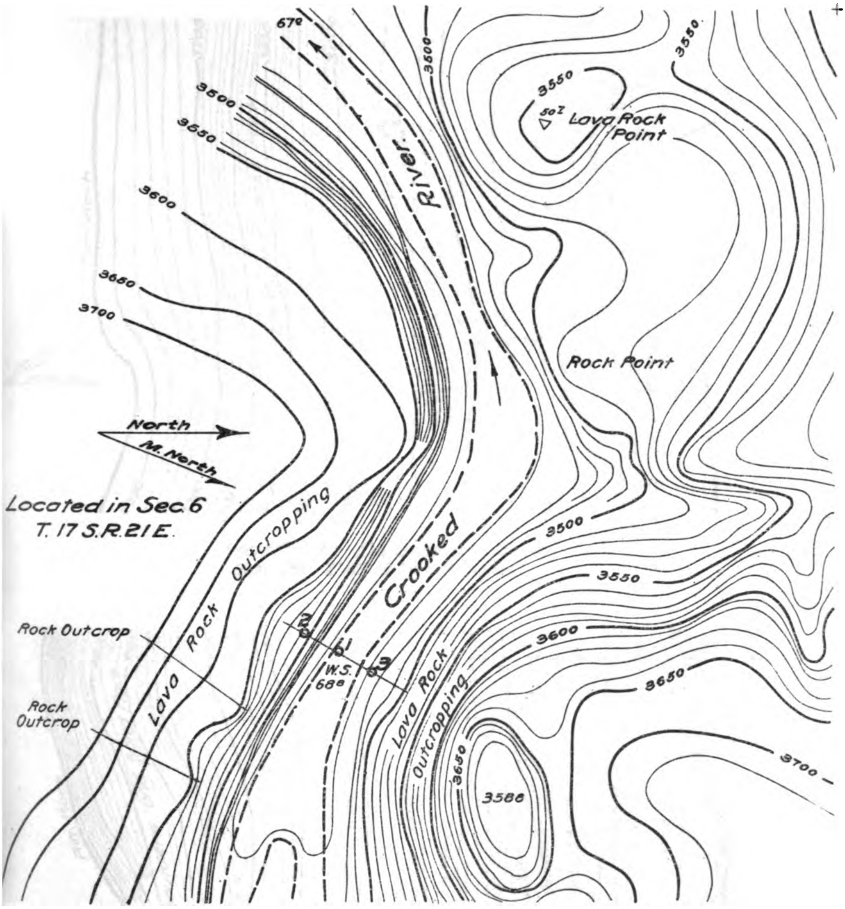
Typical Lateral Turnout

Scale of Feet

Explanation of Functions
Q=rate of flow in cu. ft. per second
A=area of water section
r=mean hydraulic radius
v=velocity of flow in ft. per second
S=slope of canal per ft.
n=coefficient of roughness

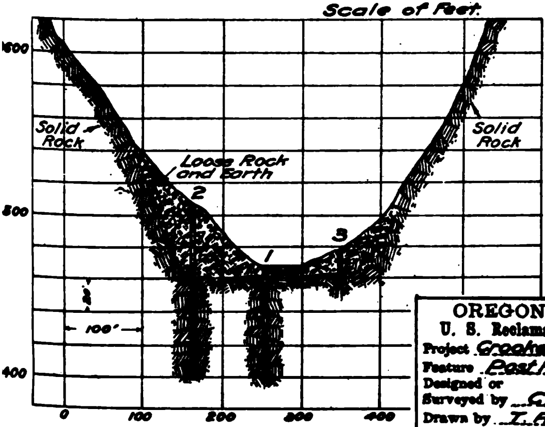
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Ochoco
Feature Canal Sections and Structures
Designed or Date
Surveyed by C.M. Whelan
Drawn by P.A.H.
Traced by "
Checked by C.E.A.B.
Scale 0 Feet. Project File No. 37

CANAL SECTIONS AND STRUCTURES.



Topography of Dam Site

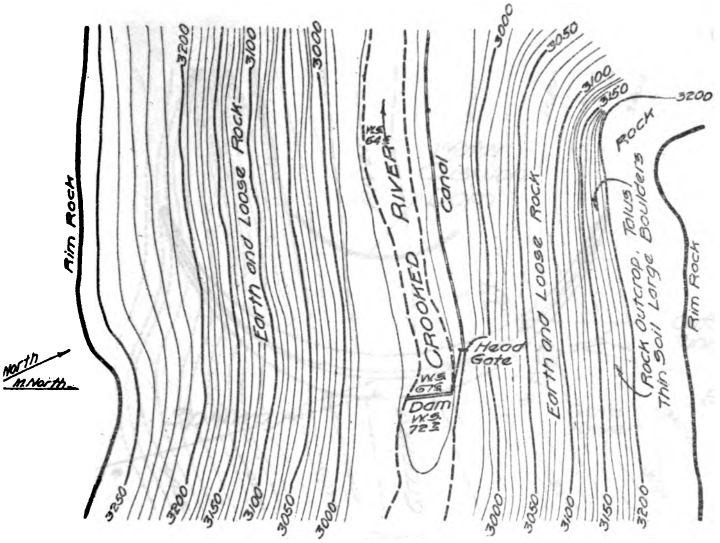
100 0 100 200 300
Scale of Feet.



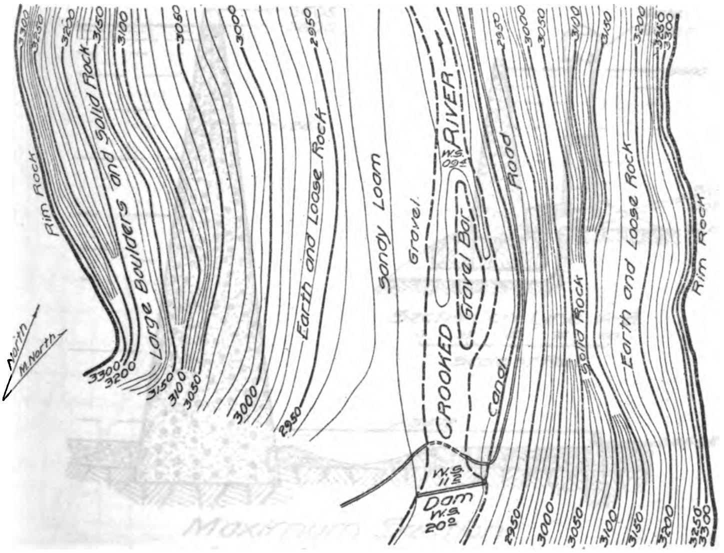
Section on line of Borings

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Post Reservoir - Dam Site
Designed or Surveyed by C. J. Date Sep. 1914
Drawn by T. R. May 1915
Traced by " "
Checked by H.L.L.
Scale Project File No. 38

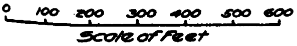
POST RESERVOIR DAM SITE.



Hoffman Diversion Site
Sec. 28, T. 16 S. R. 16 E. W.M.



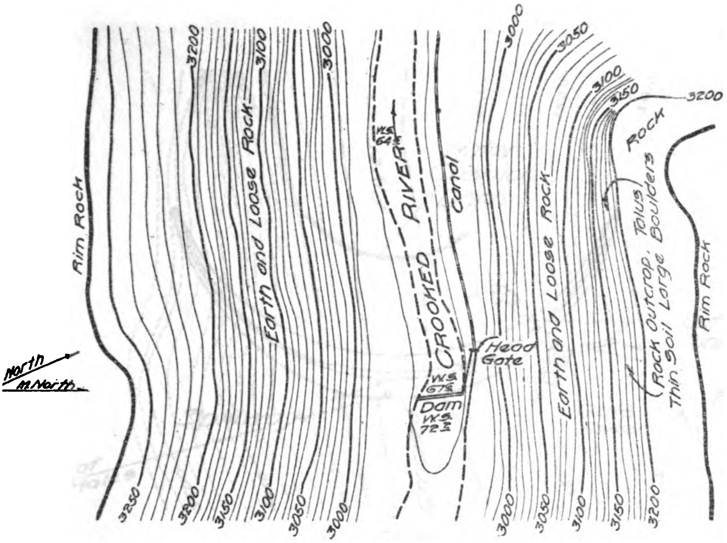
Stearns Diversion Site
Sec. 1, T. 16 S. R. 15 E. W.M.



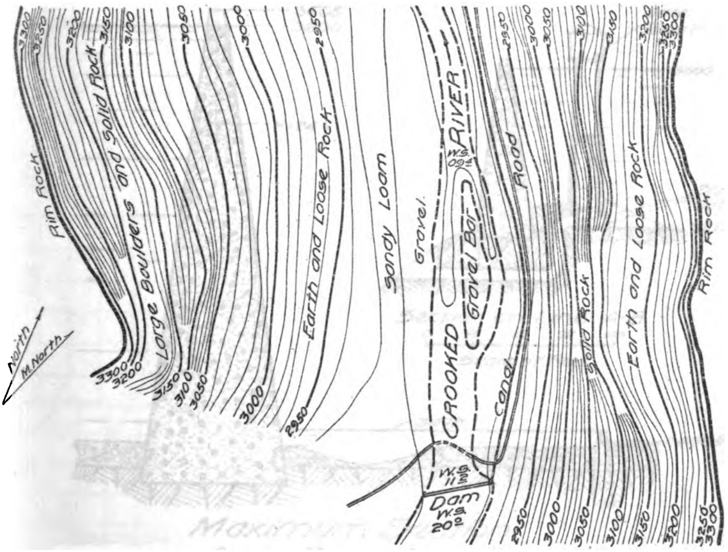
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Stearns and Hoffman Diversion Sites
Designed or Surveyed by G.M.W. Date Sept '14
Drawn by "
Traced by P.A.H. April '15
Checked by C.M.W.
Scale 0 100 200 Feet Project File No. 39

STEARNS AND HOFFMAN DIVERSIONS.

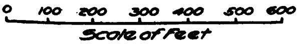
Plate 39



Hoffman Diversion Site
Sec 28, T.16 S. R.16 E. W.M.

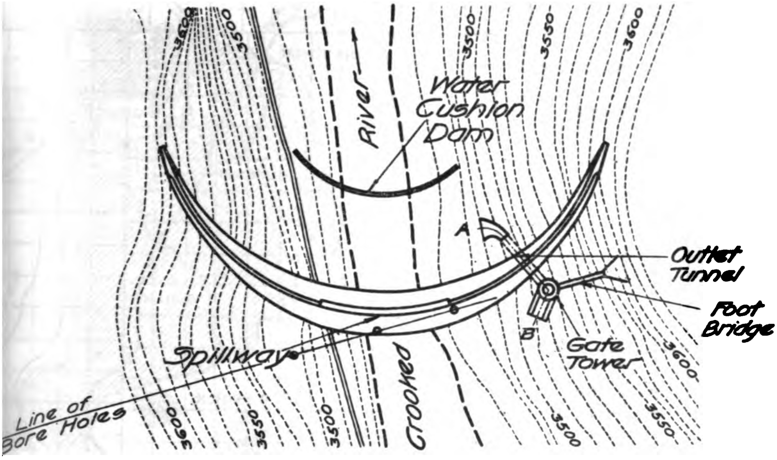


Stearns Diversion Site
Sec. 1, T. 16 S. R. 15 E. W.M.

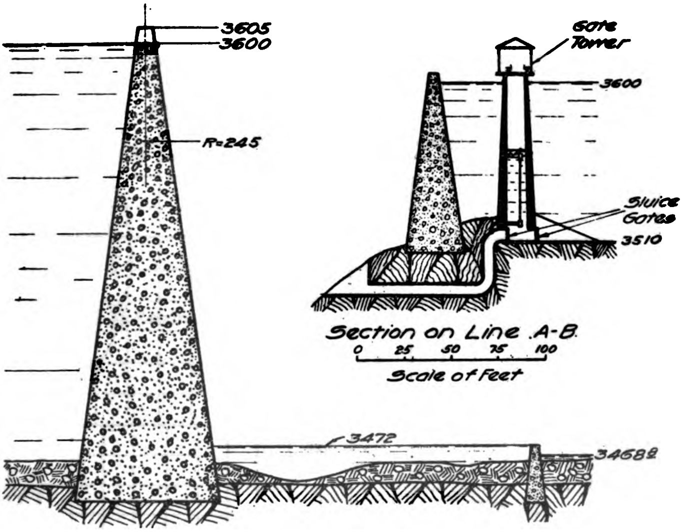


OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Stearns and Hoffman Diversion Sites
Designed or Surveyed by C.M.W. Date Sept '14
Drawn by "
Traced by P.A.H. April '15
Checked by C.M.W.
Scale 0 100 200 Feet Project File No. 39

STEARNS AND HOFFMAN DIVERSIONS.



Plan



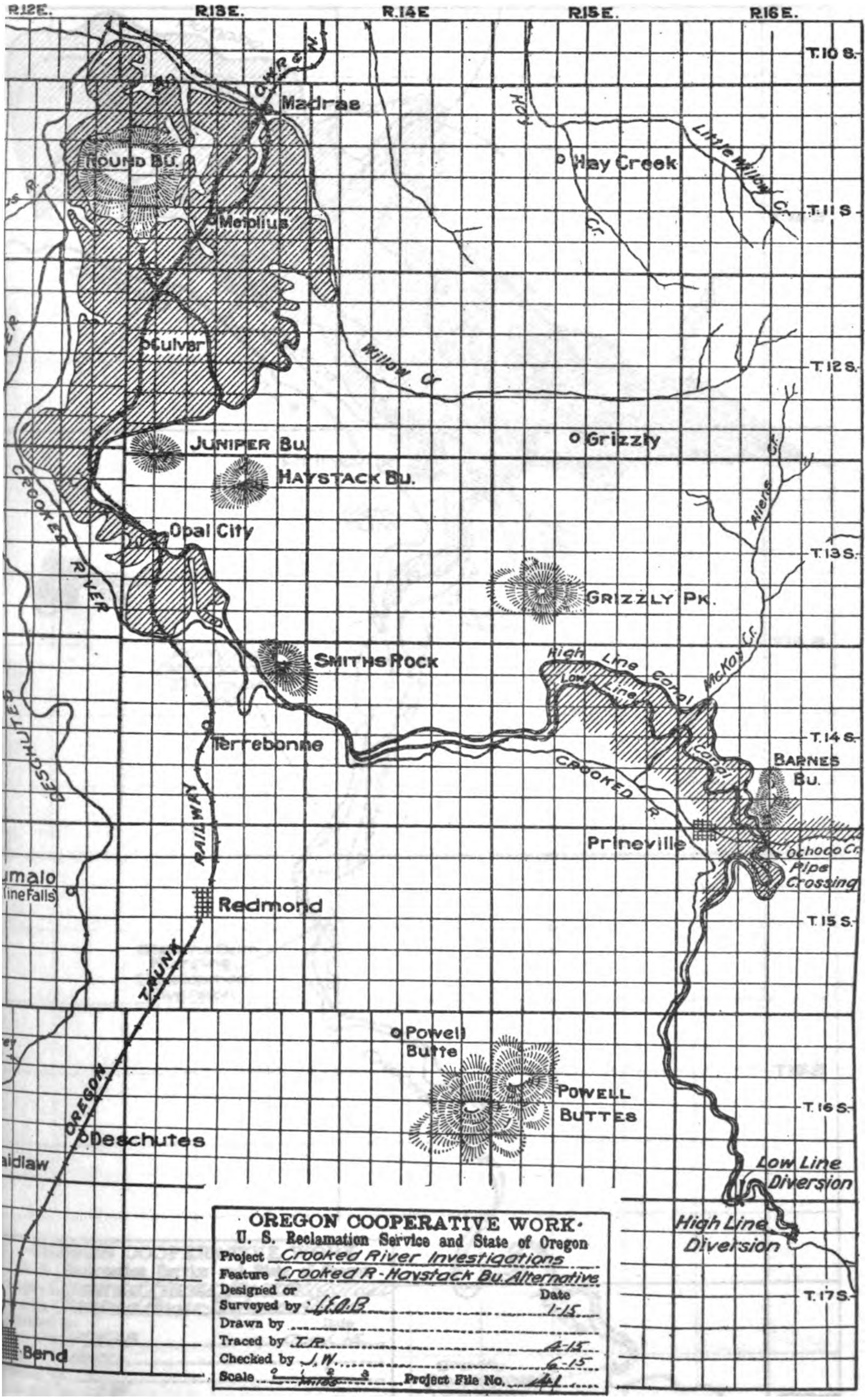
Section on Line A-B

Maximum Section

OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Post Reservoir - Design for Dam
Designed or Date
Surveyed by C.E.A.B. 4-15
Drawn by P.A.H. 4-15
Traced by 4-15
Checked by J.W.
Scale Project File No. 40

POST RESERVOIR. DESIGN FOR DAM.

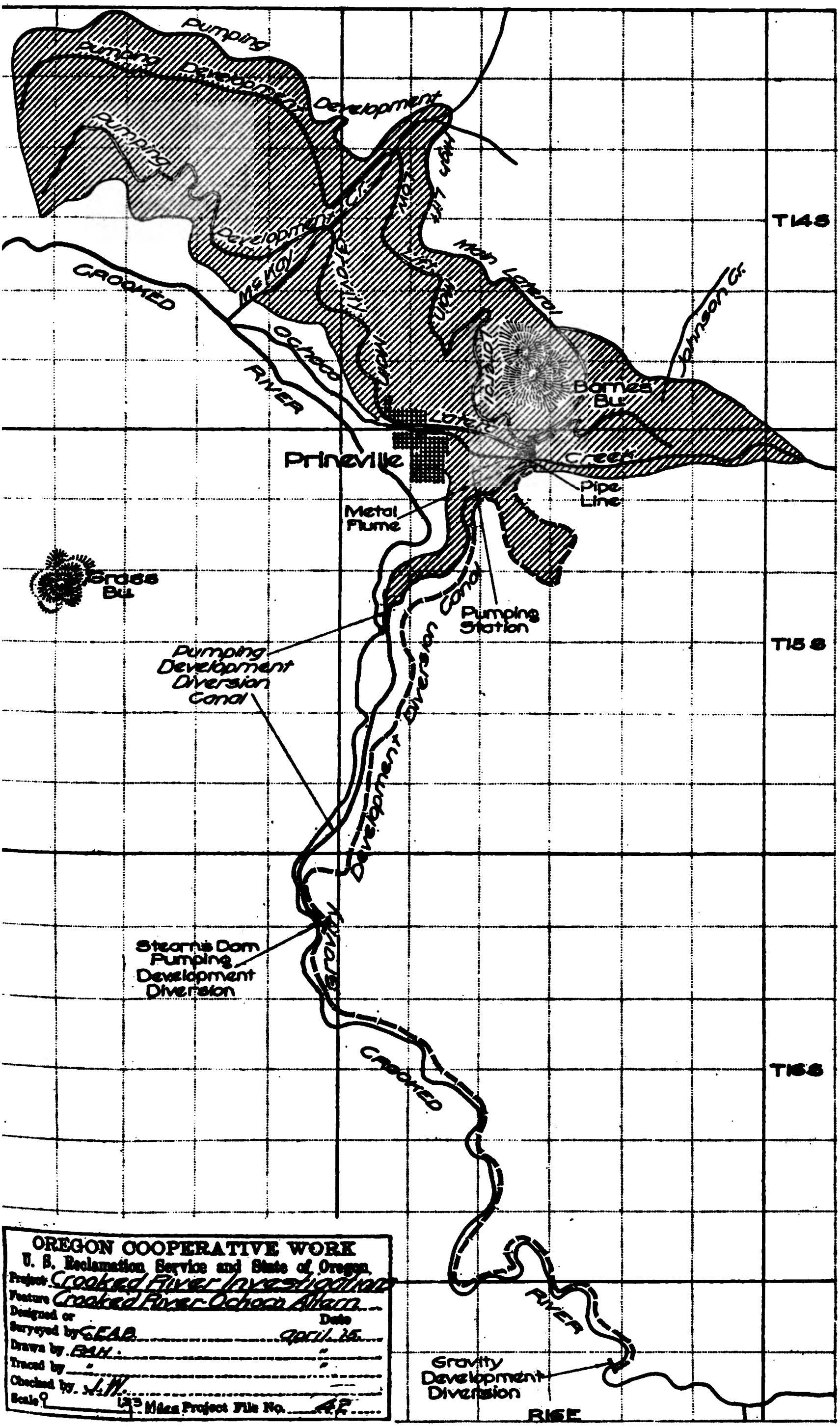
Plate 41



OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Crooked R-Haystack Bu. Alternative
Designed or Surveyed by U.S.R.S. Date 1-15
Drawn by
Traced by T.R. 4-15
Checked by J.W. 6-15
Scale 0 1 2 3 Miles Project File No. 41

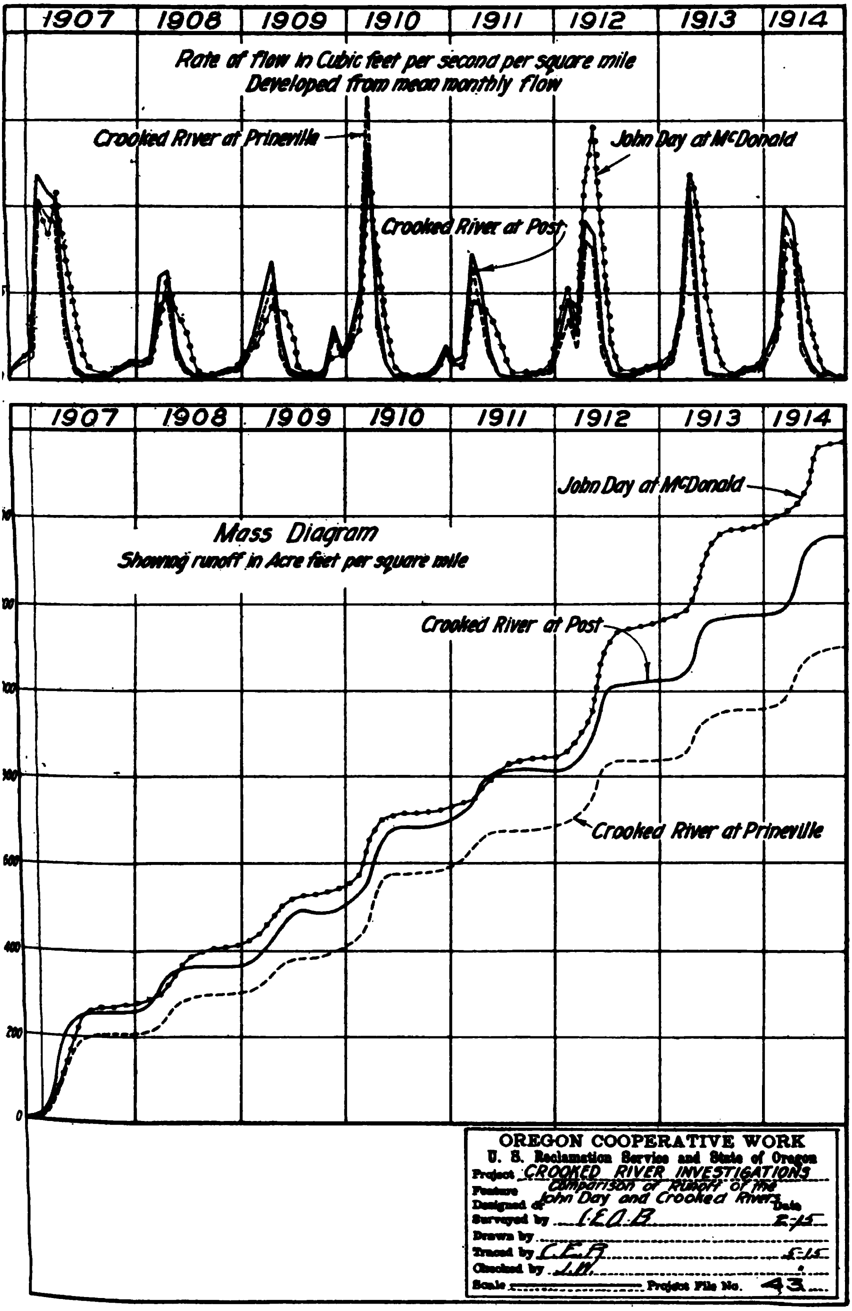
CROOKED RIVER. HAYSTACK BUTTE ALTERNATIVE.

Plate 42



OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigation
Feature Crooked River-Ochoco Altern.
Designed or Surveyed by C.E.A.B. Date April 15
Drawn by B.A.H. "
Traced by " "
Checked by J.W.
Scale 0 1 2 3 Miles Project File No. 42

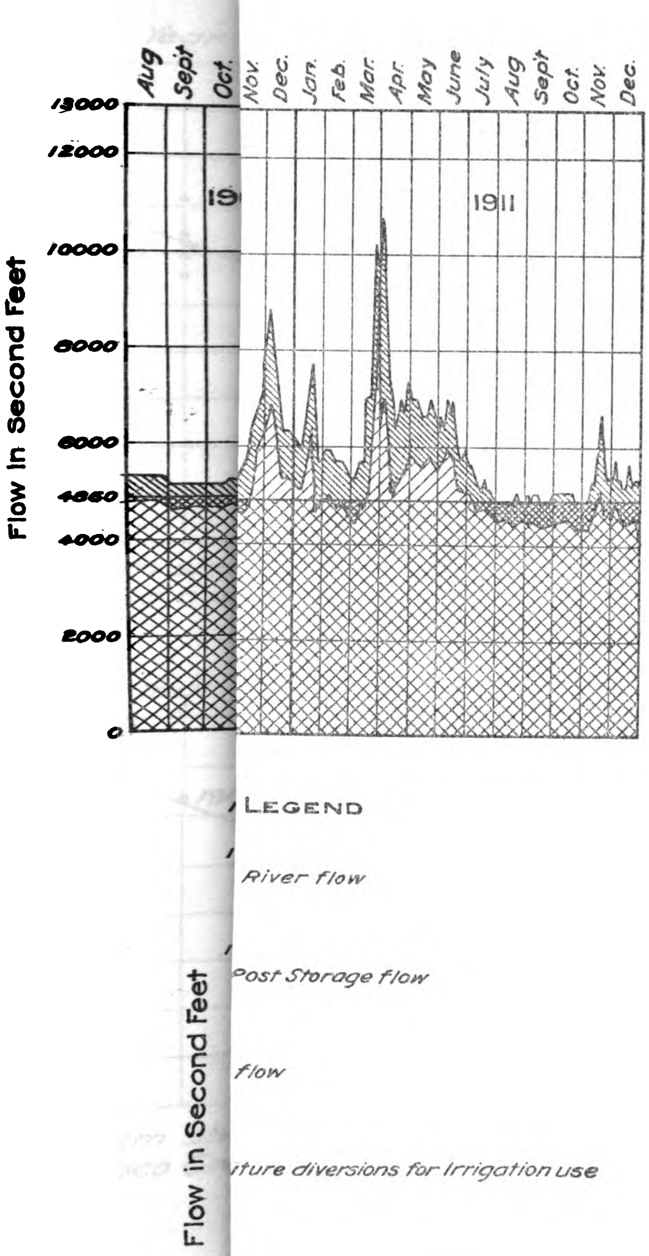
CROOKED RIVER. OCHOCO ALTERNATIVE.



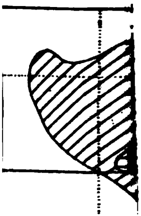
OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project CROOKED RIVER INVESTIGATIONS
Feature Comparison of Runoff of the John Day and Crooked Rivers
Designed of
Date
Surveyed by C.E.O.B. 2-15
Drawn by
Traced by C.E.B. 5-15
Checked by J.M.
Scale Project File No. 43

1. COMPARISON OF RUN-OFF OF THE JOHN DAY AND CROOKED RIVERS.

Plate 44



OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigations
Feature Hydrograph Deschutes - Moody
Designed or Surveyed by J.W. Date 1-15
Drawn by J.W.
Traced by T.R. 2-15
Checked by J.L.O.B.
Scale Project File No. 44



LEGEND

(Valley)

Dark Fine Sandy Loam

Silt Loam - Black

Fine Sand

(Upland)

Medium Sandy Loam

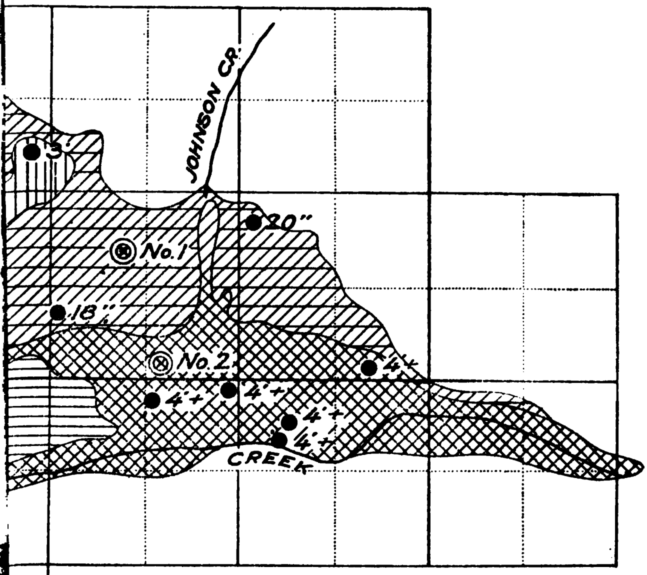
" " " *Heavy Phase*

Medium to Fine Sand

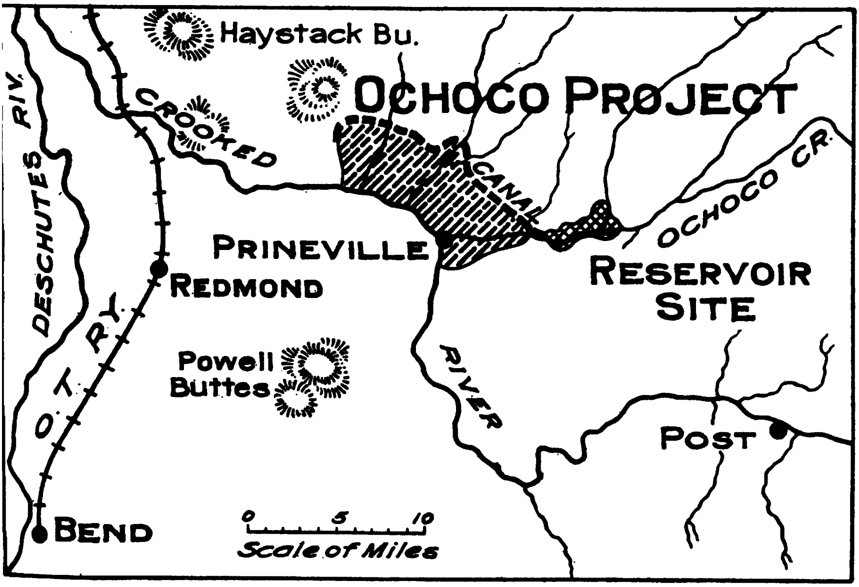
Fine Sandy Loam

Boring and Soil Depth

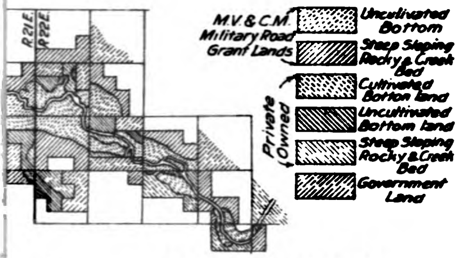
Sample and Soil Depth



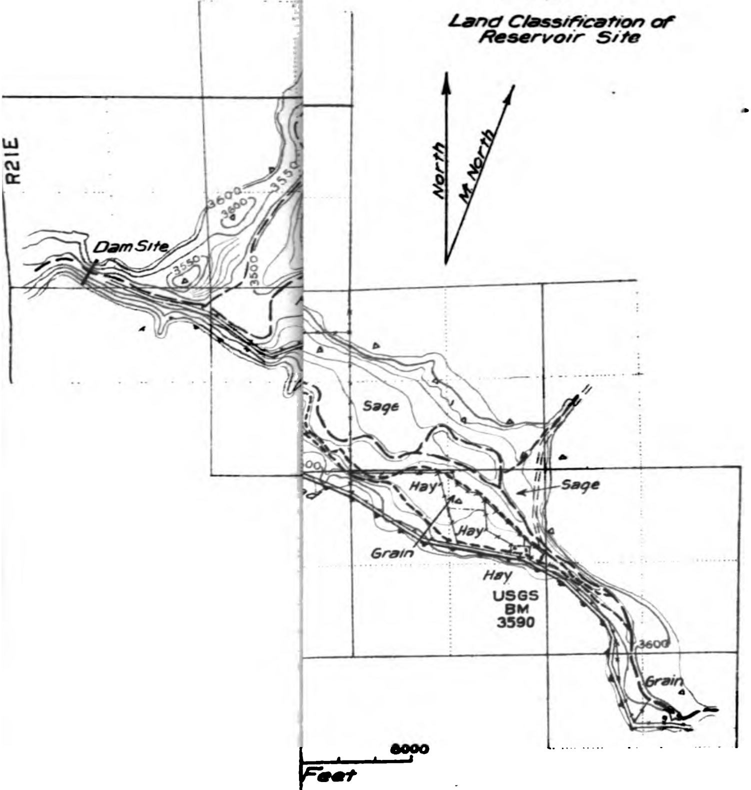
OREGON
U. S. Reclam
Project ...Ro
Feature ...Soi
Designed or
Surveyed by ...
Drawn by ...
Traced by ...T.
Checked by ...W.
Scale ...



VICINITY MAP OF OCHOCO PROJECT.



Land Classification of Reservoir Site



OREGON COOPERATIVE WORK
U. S. Reclamation Service and State of Oregon
Project Crooked River Investigation
Feature Post Reservoir Site
Designed or Surveyed by W.R.P. Date 9-14
Drawn by
Traced by G.B. 2-15
Checked by W.R.P. 2-15
Scale Project File No. 49

THE NORRIS PETERS CO., WASHINGTON.

Plate 49

89088901822

B89088901822A